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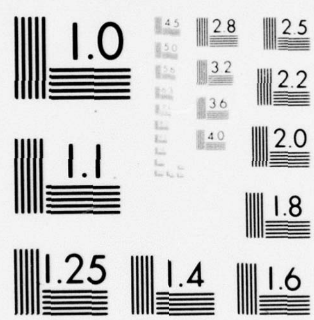

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TECHNICAL REPORT H-77-12

PUMPING STATIONS FOR DRAINAGE DISTRICT NO. 17, MISSISSIPPI COUNTY, ARKANSAS

Hydraulic Model Investigation

by

Peter E. Saunders

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

May 1977
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, Memphis
Memphis, Tenn. 38103

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a hydraulic model investigation of an existing pumping station and a 700-cfs-capacity pumping station proposed to provide additional flood protection for Drainage District No. 17, Mississippi County, Arkansas. A 1:12-scale model of the proposed pumping station, the existing pumping station, and the approach channel was used to determine flow patterns and velocities in the approach channel and to determine pressure fluctuations and vortex action within the pump sumps of the proposed station.

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20. ABSTRACT (Continued)

The model investigation indicated a large eddy in the approach channel that caused air-entraining vortexes within the sumps and large pressure fluctuations at the pump intakes. These problems were relieved by adding an earth berm separating the two stations, round pier noses, and cylindrical quadrant walls at the proposed station, by raising the baffle wall behind the pumps at the proposed station, and by adding transverse, vertical baffle walls within the sumps in the proposed station.

PREFACE

The hydraulic model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army (OCE), on 20 June 1975, at the request of the U. S. Army Engineer District, Memphis.

The investigation was conducted during the period July 1975-May 1976 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Mr. Henry B. Simmons, Chief of the Hydraulics Laboratory, and Mr. John L. Grace, Jr., Chief of the Structures Division, and under the general supervision of Mr. Joseph P. Bohan and Mr. Noel R. Oswalt, former and present Chief, respectively, of the Spillways and Channels Branch. The engineer in immediate charge of the model was Mr. Peter E. Saunders, assisted by Messrs. Bobby P. Fletcher, Robert Bryant, Jr., and Benjamin E. Beard. This report was prepared by Mr. Saunders.

During the course of the investigation, Messrs. C. Thomas and H. Wardlaw of the Memphis District, Joseph Harz of the Lower Mississippi Valley Division, and John Robertson of OCE visited WES to discuss the program of model tests, observe the model in operation, and correlate test results with concurrent design work.

Commanders and Directors of WES during the conduct of this investigation and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
feet per second	0.3048	metres per second
acres	0.4046856	hectares
cubic feet per second	0.02831685	cubic metres per second
gallons (U. S. liquid) per minute	0.003785412	cubic metres per second
pounds per square inch	0.0703	kilograms per square centimetre

PUMPING STATIONS FOR DRAINAGE DISTRICT NO. 17

MISSISSIPPI COUNTY, ARKANSAS

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Drainage District No. 17 is located in Mississippi County, Ark., just south of the Missouri State line. It lies 60 miles* north of Memphis, Tenn., and is bounded on the east by Blytheville, Ark. The existing flood control measures within Drainage District No. 17 consist of several drainage ditches and a 375-cfs-capacity (168,000-gpm) pumping station (Figure 1). These facilities drain an area of about 21,250 acres.

2. Drainage District No. 17 is subject to frequent flood damage, principally in the form of crop losses. Therefore, improvements have been proposed to provide greater flood protection by enlarging and clearing vegetation in several miles of drainage ditches and constructing an additional pumping station with a 700-cfs (314,000-gpm) capacity to pump storm runoff into the state line outlet channel.

3. The proposed pumping station will be located 90 ft from the existing pumping station on Ditch No. 71 (Plate 1). The proposed station will consist of three vertical-shaft, mixed-flow pumps operated by diesel engines. Each pump will have a rated capacity of 233 cfs (104,000-gpm) at 25 ft of pumping head and an air-vented, over-the-levee-type discharge line.

Purposes of the Model Investigation

4. Pump performance can be adversely affected by air entrainment,

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

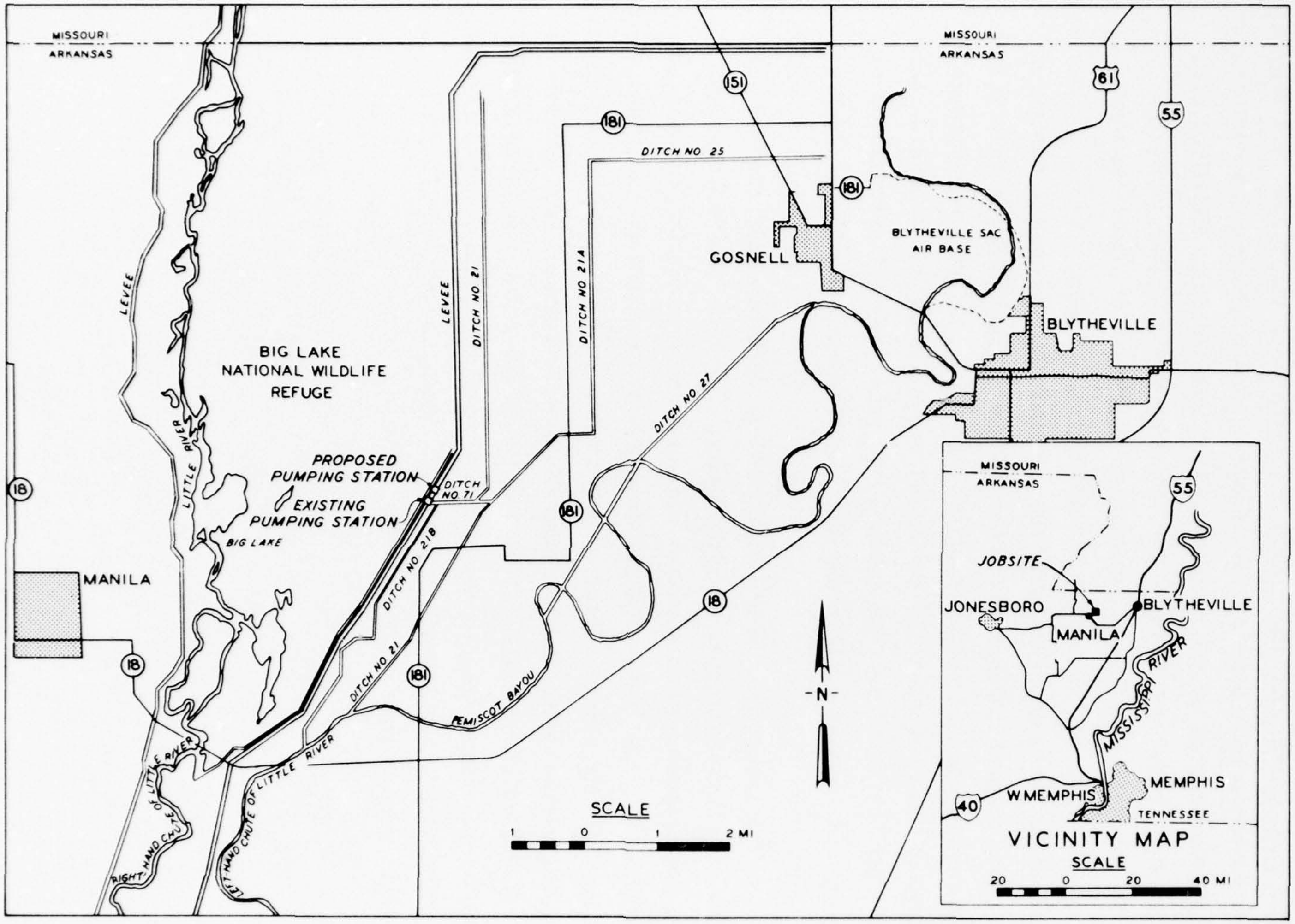

Figure 1. Vicinity map and details of flood-control measures in the project area

vortex action, and uneven flow distribution at the pump intake. These adverse flow conditions can result in cavitation, vibration, and uneven stress on the pump. Some of the causes of these adverse flow conditions are low submergence of the pump impeller, wave action, dissolved air, and the rotational momentum of the water approaching the intake.[1,2]

5. Studies have been conducted to determine the optimum shape of the pump intake and the proper distance from the sump walls.[3-5] However, few criteria are available for determining the proper design of approaches to pump intakes, even though the approach design is critical to pump performance. Because of this lack of criteria for approach design and the fact that the pumps and motors represent a considerable portion of the total project cost, a hydraulic model investigation of the proposed pumping station for Drainage District No. 17 was deemed necessary.

6. The investigation was conducted to determine and improve, if necessary, characteristics of flow approaching both the proposed and the existing pumping stations for various combinations of pump and station operations and various water levels. It was also desired that construction of the proposed station and its operation, either independently or in conjunction with the existing station, not create any adverse effect on the existing station. In addition, the model was to be used to determine the riprap requirements upstream of the pumping stations and to determine practical design changes for ensuring satisfactory hydraulic performance.

PART II: THE MODEL

Description

7. The model (Figure 2) was constructed to an undistorted linear

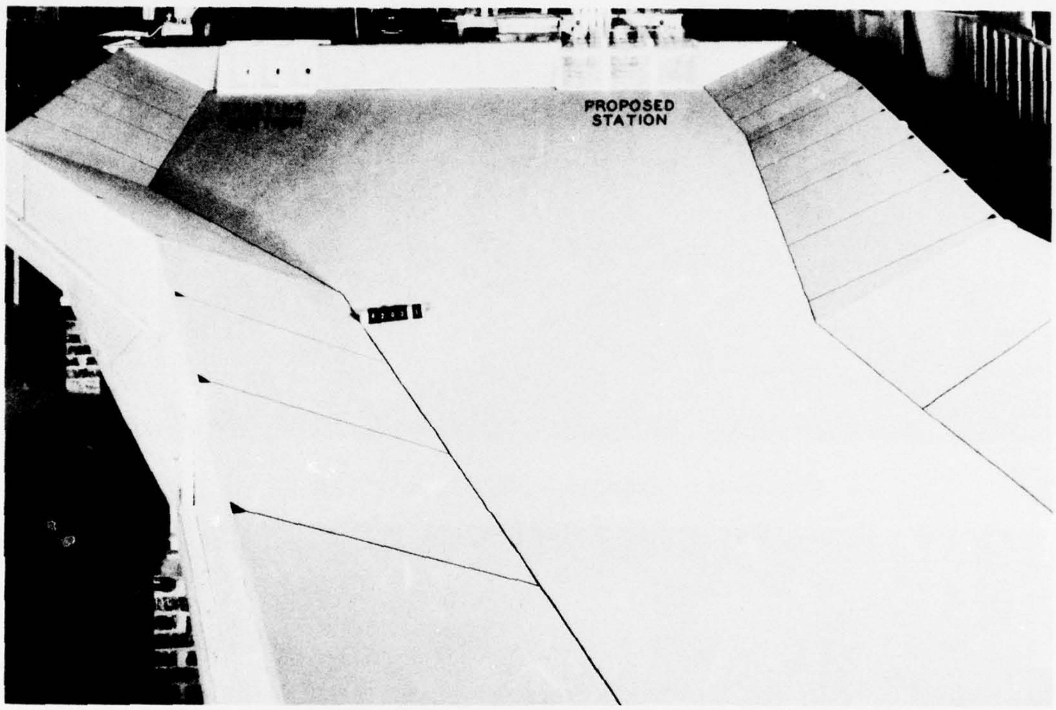

Figure 2. Overall view of the model (original design) approach

scale ratio of 1:12. It reproduced approximately 400 ft of approach channel, the general geometry of the existing pumping station, and the detailed geometry of the proposed pumping station. The approach channel and existing pumping station (Figure 3) were constructed of plywood. The proposed pumping station and its pump intakes (Figure 4) were constructed of plastic to permit visual observation of flow approaching and entering the pump intakes. Trash racks were simulated with a mesh formed from brass rods.

8. Flow through the simulated pump columns was recirculated by individual suction pumps in both stations. Inflow and outflow discharges

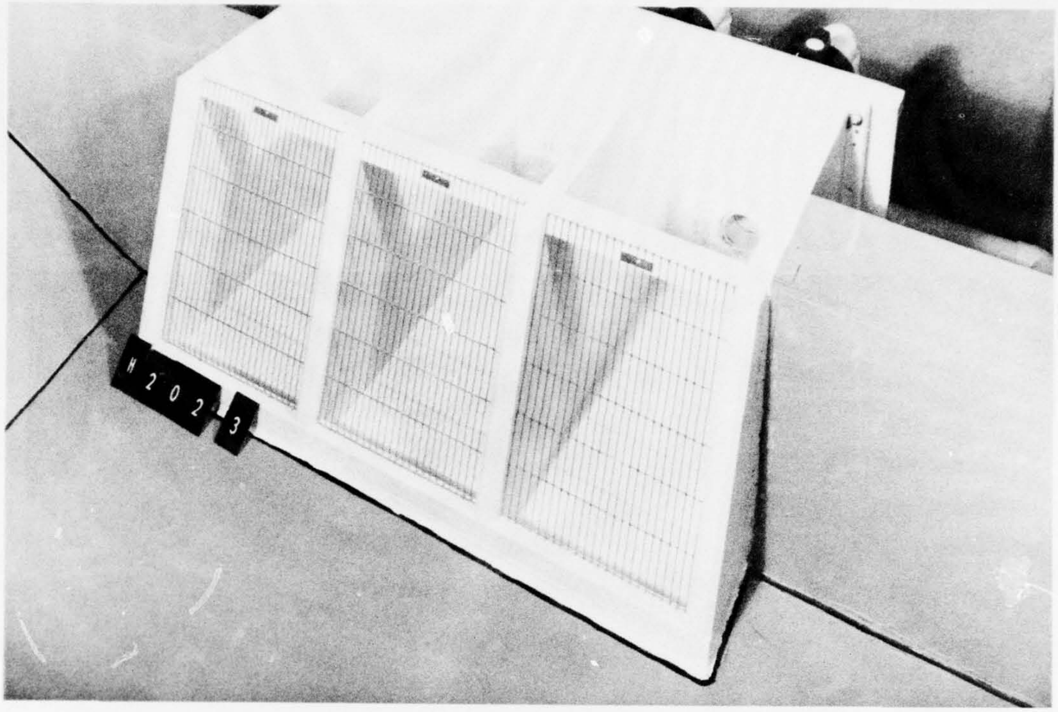

Figure 3. Existing pumping station

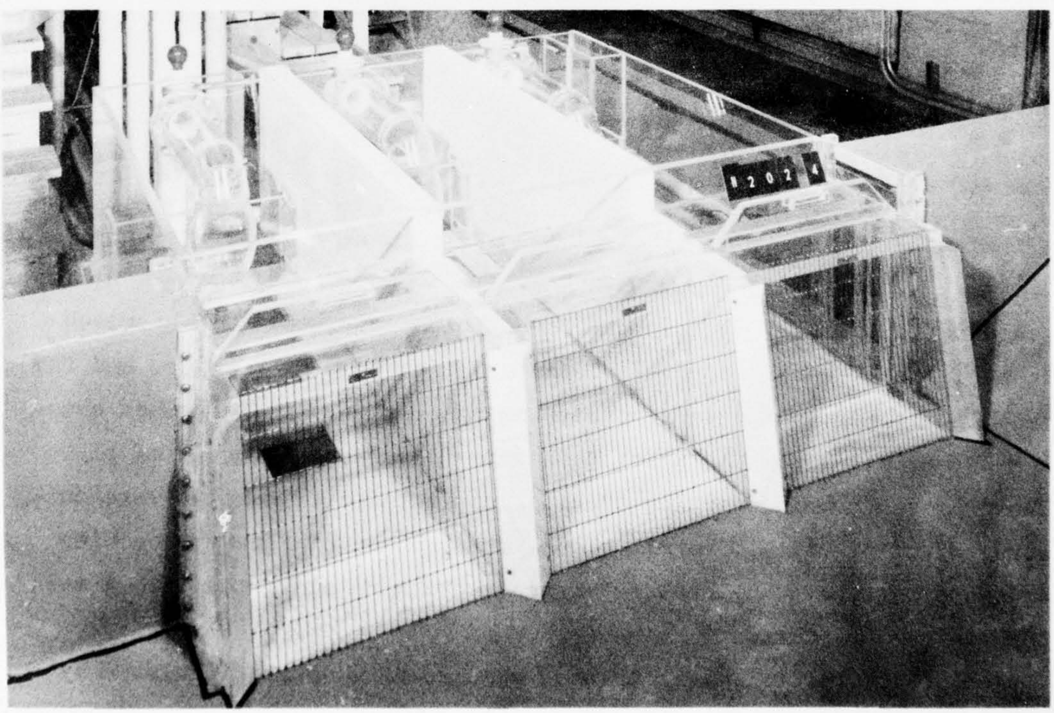

Figure 4. Proposed pumping station (original design)

were controlled by butterfly valves and measured with calibrated turbine flowmeters. Pressure fluctuations on the floor of the sump directly underneath the proposed pump intakes were measured with 15-psia pressure cells and recorded on an oscillograph. Surface and subsurface flow patterns were observed and photographed using both confetti and dye.

Interpretation of Results

9. The predominant forces affecting flows in an approach channel and pump chambers are inertia and gravity. Under such conditions, hydraulic similarity between model and prototype requires that the ratio of inertial to gravitational forces, defined as the Froude number of flow, be the same in both the model and the prototype. Therefore, the accepted equations of hydraulic similitude, based upon the Froudian criteria, were used to express the mathematical relationships between the dimensions and hydraulic quantities of the model and the prototype. The general relations are as follows:

Dimension	Ratio	Scale Relation
Length	$L_r = L$	1:12
Area	$A_r = L^2$	1:144
Velocity	$V_r = L^{1/2}$	1:3.464
Discharge	$Q_r = L^{5/2}$	1:498.8
Roughness	$N_r = L^{1/6}$	1:1.513

10. The predominant forces affecting pressure flow within a conduit are inertia and viscosity, and the ratio of inertial forces to viscous forces (Reynolds number) will be equal in model and prototype if the ratio of model and prototype Reynolds number is unity. It is impossible to preserve both Froudian and Reynolds similarity in an undistorted model built to a practical scale using the same fluid. However, it is not necessary that the Reynolds number of flow in the

model equal that in the prototype, provided the same fundamental character of flow is preserved in the model. It generally suffices that the model be large enough to ensure fully developed turbulent flow similar to that which will exist in the prototype.

11. Obviously, flow within a pump intake is influenced by inertial, gravitational, and viscous forces. Upon entering the pump column, the predominant forces transition from the inertial and gravitational to the inertial and viscous. This transitional flow condition and fundamental character of flow can be represented in a model provided it is constructed according to the Froudian criteria for similitude and is large enough to ensure fully developed turbulent flow within the model sump. The model of the pumping stations in this investigation produced Reynolds numbers of flow greater than 3×10^4 and turbulent flow in the approaches to the pumps. This size model is considered to be capable of yielding reliable indications of prototype behavior.[6,7]

PART III: TEST RESULTS

Method of Operation

12. The proposed pumping station (Plate 2) will consist of three pumps operating in individual sumps. The invert of each sump will be at el 221* with each pump suction bell at el 223.5. The pumps will be started manually and stopped automatically. It is planned to operate the station in the following manner: One pump will be started when the water level in the sump reaches el 229; a second pump will be started when the water level reaches el 230; and the third at el 231. All pumps in operation will be stopped when the water level drops to el 228.

13. Frequently, only one or two pumps will be needed to reduce the water to the shutdown level. This fact makes it necessary to alternate pumping cycles so that there will be equal wear on all pumps. Also, there will be a manual override to the automatic shutdown to prevent the pumps from shutting off due to waves and surges. The proposed station will be able to operate independently or in conjunction with the existing station.

Original Design

14. Photo 1a shows flow patterns in the approach channel with the water level at el 228 for the proposed station operating independently. Photo 1b shows both stations operating. Photos 2a and 2b show similar patterns observed with the maximum anticipated water level of 235.5. A large counterclockwise eddy, formed in the simulated excavated area in front of and between the pumping stations, caused uneven distribution of flow entering the individual sumps. The uneven flow produced eddies and dead areas in the individual sumps as well as vortexes and uneven pressure distribution at the pump intakes.

15. Vortex formation was indicated for almost all combinations

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* All elevations (el) cited herein are in feet above mean sea level (msl).

of pump operation and water level, and most of the vortexes visibly entrained air from the surface (Figure 5) and persisted for 20 to 50 sec (prototype time) before breaking up. Location and strength of vortex

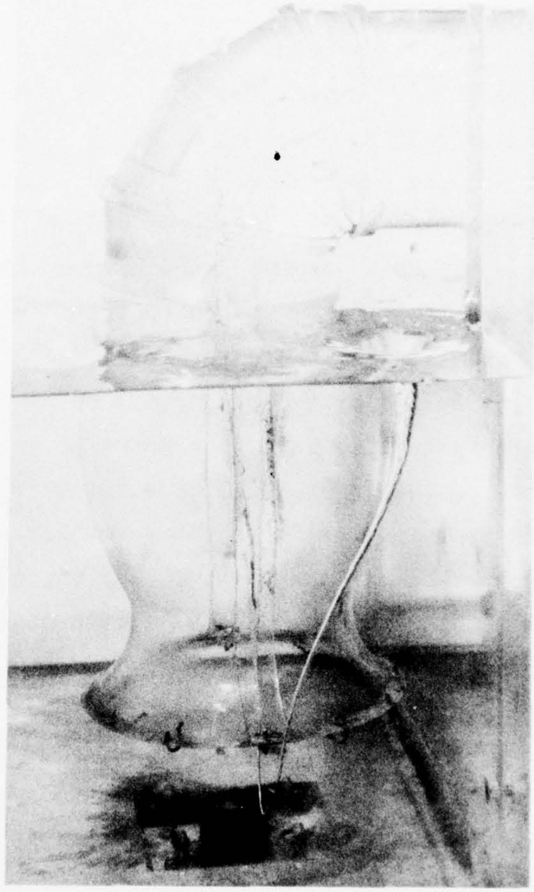

Figure 5. Air-entraining vortex
in original design

action in the model appeared to be directly related to the distribution of flow entering the individual sumps and the submergence of the pump intakes. However, the largest and strongest vortexes occurred at a medium submergence (sump el 231). This phenomenon is attributed to the termination of the baffle wall behind each pump intake at el 230 (which permitted a sudden increase in surface area when the water level was above el 230) for there was a greater tendency for surface eddy formation within the sump with a water surface elevation of 231. The shape

of the approach channel (side slopes of 1V on 2H) permitted an increased approach surface area with the higher stages and sump levels and thus also contributed to vortex formation.

16. Pressure readings in the vicinity of pump intakes can provide useful information for evaluating pumping station design.[8,9] Plate 3 presents typical results (in prototype dimensions) obtained from pressure cells located on each sump invert directly beneath the center of the pump intake. Plate 4 demonstrates the range of pressure fluctuations recorded for various combinations of pump operation and water level. Appearances and disappearances of vortexes did not correspond to the peaks on the pressure cells. Despite the fact that pressure fluctuations and vortexes were caused by the uneven flow distribution, peak pressure fluctuations did not occur at the same time as vortex action.

Type 2 Approach Channel

17. To eliminate the large eddy in the approach channel, a divider berm was placed between the two pumping stations (Figure 6). Also, the

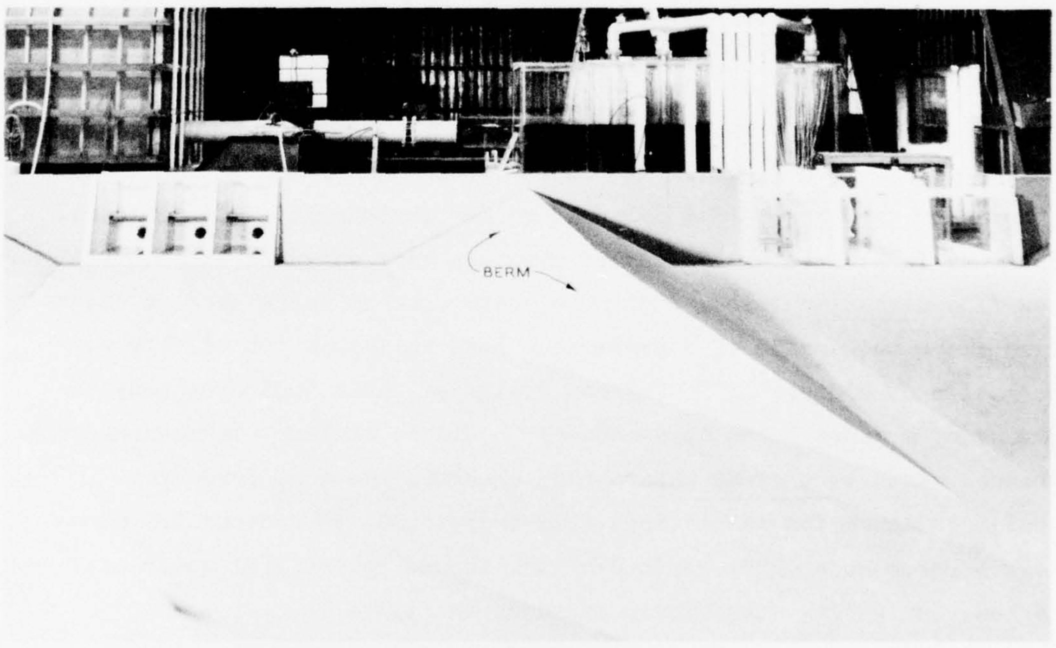

Figure 6. Type 2 approach channel

baffle wall behind the pump intakes was raised to el 235.5. The resulting flow patterns in the approach channel are shown in Photos 3 and 4.

18. Although the large eddy was broken up, a strong eddy still developed in each approach and caused uneven flow and vortexes within the individual sumps. Nevertheless, the vortex action within the individual sumps was greatly reduced with the type 2 approach channel. There were no air-entraining vortexes of the same magnitude or duration as those observed with the original design. Again, the most pronounced vortex action occurred for a sump water level of approximately 231.

19. A comparison of Plates 4 and 5 indicates that no significant improvement in pressure fluctuations was obtained with the type 2 approach channel. There was some improvement during the operation of particular individual and pairs of pumps, but pressure fluctuations increased with operation of all three pumps. Asymmetrical flow conditions approaching the pumping stations were considered the major factor in producing vortexes and pressure fluctuations. Tests of various approach channel designs were therefore continued.

Type 9 Approach Channel

20. The main problems encountered in the approach flow were separation of flow along curves in the approach channel and in the transitions from the trapezoidal channels to the rectangular pump chambers. Previous investigations of curved channels have shown that geometric and flow discontinuities, such as a sharp drop in water surface elevation along the inside of a curve, can lead to separation of flow and formation of eddies.[10,11] Current design guidance indicates that the radius of a curve in an open channel should be at least three times the channel width to prevent separation, erosion, and eddy formation.[11-13] Design guidance for transitions from trapezoidal to rectangular channels[13] recommends three basic designs, termed cylindrical quadrant, warped, and wedge transitions, as shown in Figure 7.

21. The cylindrical quadrant type of transition was selected as the most practical alternative for improving the design of the approach

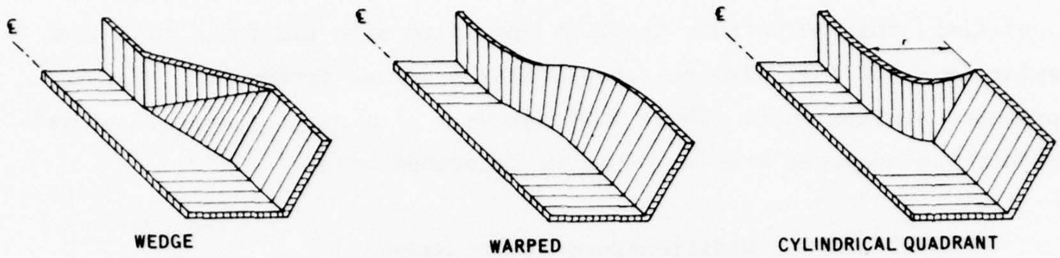

Figure 7. Basic designs for trapezoidal to rectangular channel transitions

channel for this project. The design developed incorporated such a transition from the approach channel to the sumps, as shown in Figure 8. The 32-ft-radius cylindrical quadrant provided satisfactory flow conditions at the pump intakes and only minor surface vortex action under all operating conditions.

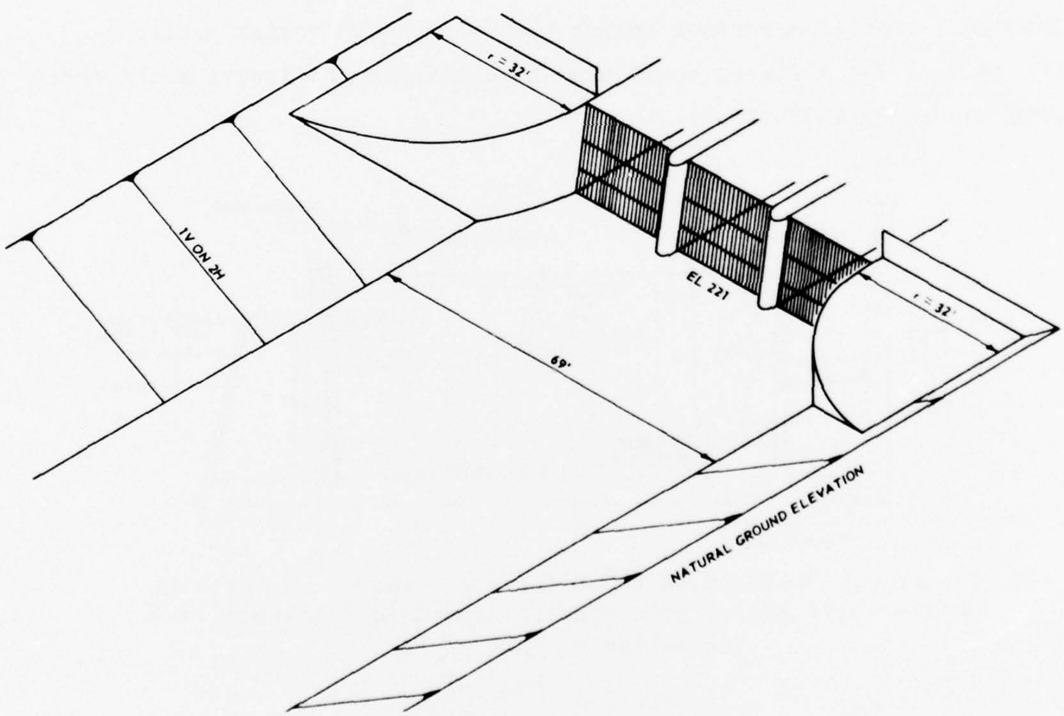

Figure 8. Recommended approach channel transition

22. The existing and proposed stations operated satisfactorily for all water level and pump operation combinations except for one

condition, that being both stations operating with all pumps at a sump water level of 231. For this condition, a vortex formed within each proposed station sump. These vortexes were eliminated by modifications within the proposed station sumps as described below.

Modifications Within Sumps

23. Several modifications within the individual sumps were tested, including baffles of various heights at different locations, guide vanes, modifications of the trash rack, various changes in the sump dimensions, and coverging side walls. The most effective modification was the installation of a transverse, vertical baffle wall one and one-half bell diameters upstream of the center line of each pump. This wall extended across the full width of each sump to alter flow above el 230 (Figure 9). This wall created a surface roller that eliminated vortex action (Photo 5). The vortexes could also be eliminated by lowering the entry gate to el 229.2 (Photo 6).

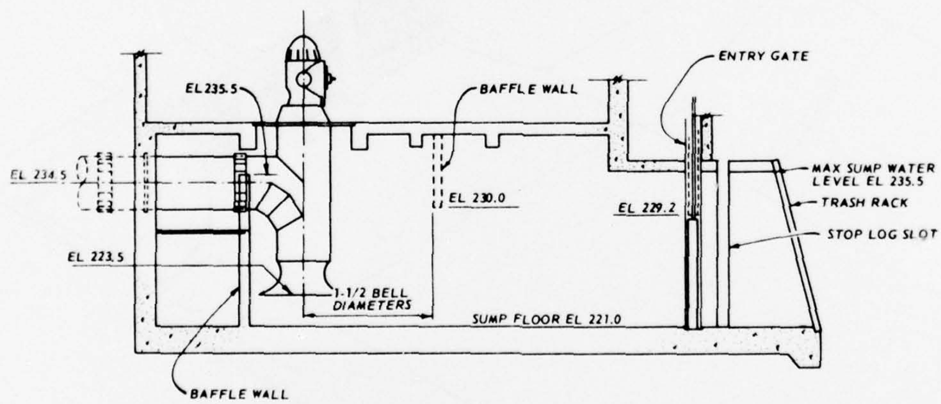

Figure 9. Recommended locations for transverse, vertical baffle wall, and/or gate opening needed to eliminate vortex action at sump el 231

Recommended Project Design

24. The final recommended channel and sump designs (Plates 6 and 7) include a divider berm and cylindrical quadrant transitions in the

approach channel (Type 9 approach channel design), a vertical extension of the baffle walls behind the pump intakes from el 230 to el 235.5, rounded pier noses at the entrance, and baffle walls from the roof of the pump chambers to el 230. The baffle walls from the roof of the pump chambers are needed to prevent the air-entraining vortexes that appeared very infrequently with the sump water level at el 231. It is possible that lowering the entry gate to el 229.2 may be more economical than installing a permanent baffle wall within each sump, but adverse flow might still be induced with improper operations. A comparison of the pressure fluctuations observed with the permanent baffle wall and the lowered entry gate is presented in Plate 8.

25. Flow patterns observed with the recommended design are shown in Photos 7 and 8. Some improvement in flow patterns compared with those for previous designs is evident, particularly at the lower water surface elevations. However, these seemingly small changes in the flow patterns greatly reduced the pressure fluctuations (Plates 9 and 10) and eliminated vortex action except for the one condition (sump el 231) where the transverse, vertical baffle wall was required. Incorporation of all of these modifications will provide satisfactory approach and sump flow conditions in both the proposed and the existing pumping stations.

Protection of Approach Channel

26. Velocity measurements were taken in front of the proposed pumping station and at the nose of the divider berm to determine if channel protection was needed. Maximum bottom velocities were measured along the channel invert and the banks (Plate 11). The measurements indicate that a good grass-lined channel will be sufficient. However, an analysis should be made of the soil type to indicate the effects of a rapid drawdown of the water surface.

Prototype Testing

27. Prototype tests of the proposed pumping station will be

conducted in the future by the U. S. Army Engineer District, Memphis, and the U. S. Army Engineer Waterways Experiment Station to verify performance of the proposed station and correlate model and prototype results. Table 1 and Plate 12 present some of the model data that will be compared with similar prototype data (minimum water surface elevations indicated by piezometers and average velocity profiles along the center line of each pump chamber and 6 ft either side of the center line). Velocity, pressure, and pump discharge measurements will be made in the prototype.

PART IV: DISCUSSION

28. To eliminate vortex action, air entrainment, pressure fluctuations, and uneven flow distribution at the pump intakes, the flow lines into each sump should be parallel with the sump walls. Ideally, there should be a long straight channel in front of the pump chamber and a very gradual transition from the channel to the pump chamber. However, this situation is not usually economically feasible. Better compliance with hydraulic design criteria for flood-control channels should produce more satisfactory flow conditions at pump intakes.

29. Relatively narrow approach channels are subject to surging when pumps are turned off or on. The diesel engines at Drainage District No. 17 will be capable of slowly building up to operating speed and should prevent any tendency to generate adverse surges. However, the problem of surging should be addressed whenever constant-speed electric motors are used in conjunction with a narrow approach.

30. The model indicated the need for modification of both approach channel and individual sump features to obtain satisfactory flow conditions with reasonably uniform distribution of velocities, minimum pressure fluctuations, and little, if any, rotational flow capable of generating adverse air-entraining vortexes. The model indicated that the proposed pumping station should not adversely affect hydraulic performance of the existing station.

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Table 1

Minimum Water Surface Elevation Indicated by Piezometers (in feet) Relative to Water Surface Elevation in Sump with Three Pumps Operating (Recommended Design)

Piezometer* No.	Sump El 228	Sump El 229	Sump El 230	Sump El 231	Sump El 235.5
1	-0.2	-0.1	-0.5	-0.3	-0.6
2	-0.2	-0.1	-0.4	-0.3	-0.4
3	-0.2	-0.1	-0.1	-0.2	-0.2
4	-0.1	-0.1	-0.1	-0.1	-0.1
5	-0.2	-0.1	-0.2	-0.1	-0.1
6	-0.2	-0.05	-0.2	-0.1	-0.1
7	-0.2	-0.05	-0.2	-0.1	-0.1
8	+0.1	+0.3	-0.1	-0.1	-0.2
9	-0.1	+0.3	-0.1	-0.05	-0.15
10	-0.2	+0.1	-0.1	-0.05	-0.1
11	-0.2	+0.1	-0.1	-0.05	-0.1
12	-0.2	0.0	-0.05	0.0	-0.1
13	-0.1	+0.2	0.0	+0.1	-0.1
14	+0.2	+0.2	0.0	+0.1	0.0
15	-0.1	-0.1	+0.05	+0.1	0.0
16	-0.1	-0.1	+0.05	+0.1	0.0
17	+0.1	-0.1	+0.2	+0.2	0.0
18	+0.2	-0.1	+0.2	+0.2	0.0
19	+0.2	+0.1	+0.2	+0.2	+0.1
20	+0.2	+0.1	+0.2	+0.1	+0.1
21	+0.2	+0.2	+0.3	+0.2	+0.2
22	-0.1	-0.1	-0.2	-0.2	-0.1
23	-0.1	-0.1	-0.2	-0.2	-0.1
24	-0.1	-0.2	-0.15	-0.2	-0.1
25	-0.1	-0.1	-0.1	-0.1	0.0
26	-0.1	-0.1	-0.15	-0.1	-0.1

(Continued)

* Piezometer locations are shown in Plate 13.

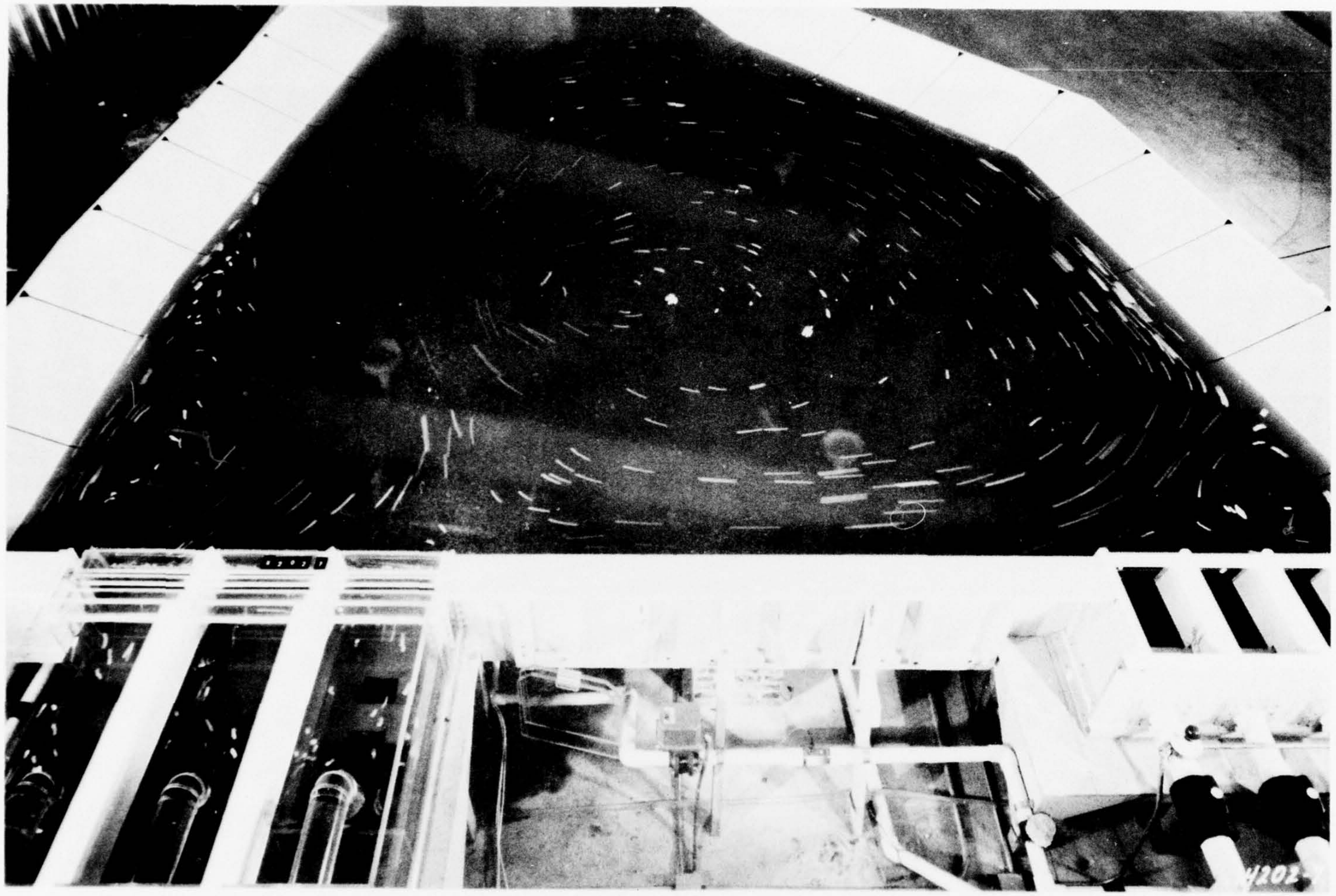
Table 1 (Continued)

Piezometer No.	Sump El 228	Sump El 229	Sump El 230	Sump El 231	Sump El 235.5
27	-0.1	-0.1	-0.1	-0.1	-0.1
28	-0.1	-0.1	-0.1	-0.05	0.0
29	-0.1	-0.3	-0.3	-0.2	0.0
30	-0.1	-0.3	-0.3	-0.2	-0.1
31	-0.1	-0.1	-0.1	-0.1	-0.1
32	-0.1	-0.1	-0.1	-0.1	-0.1
33	-0.1	-0.1	-0.1	-0.1	-0.1
34	0.0	-0.1	-0.1	-0.1	-0.1
35	0.0	-0.1	-0.1	-0.1	-0.1
36	0.0	-0.1	-0.1	-0.1	-0.1
37	-0.1	-0.1	-0.1	-0.1	-0.1
38	-0.1	-0.1	-0.1	-0.1	-0.1
39	-0.1	-0.2	-0.05	-0.1	-0.1
40	-0.1	-0.1	-0.1	-0.1	-0.1
41	-0.1	-0.1	-0.1	-0.1	-0.1
42	-0.1	-0.1	-0.1	0.0	0.0
43	-0.1	-0.01	-0.01	-0.01	-0.1
44	-0.1	-0.01	-0.01	-0.01	0.0
45	-0.1	-0.01	-0.01	-0.01	-0.1
46	+0.1	+0.1	+0.1	+0.0	+0.05
47	+0.1	+0.1	+0.1	+0.1	+0.0
48	+0.2	+0.2	+0.2	+0.2	0.0
49	+0.2	+0.1	+0.1	+0.1	+0.2
50	-0.2	-0.2	-0.1	-0.1	-0.1
51	-0.2	-0.2	-0.1	-0.1	-0.15
52	-0.1	-0.1	0.0	0.0	-0.1
53	-0.1	-0.1	0.0	0.0	-0.1
54	-0.1	-0.1	0.0	0.0	0.0
55	-0.1	-0.0	0.0	0.0	0.0

(Continued)

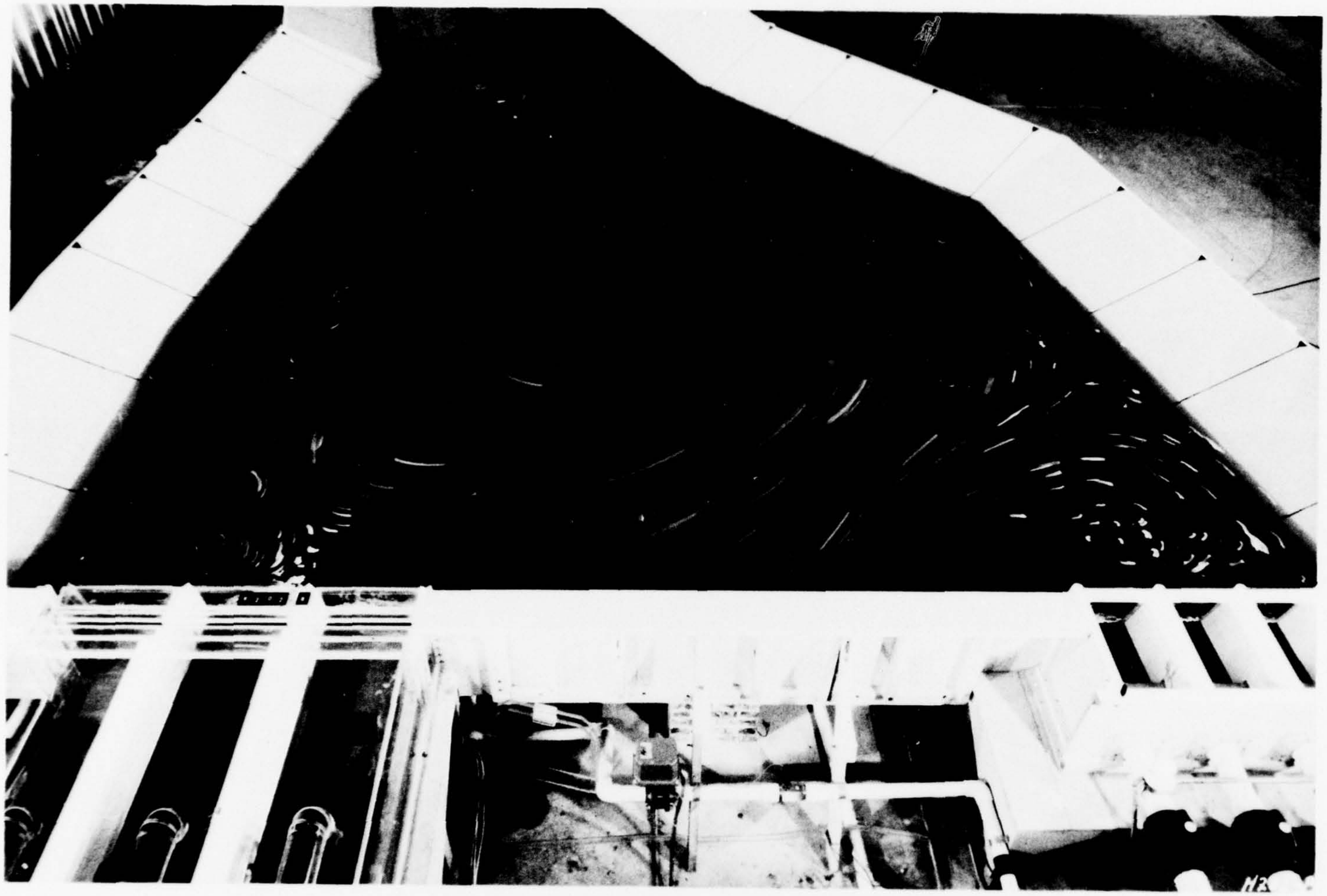
Table 1 (Concluded)

Piezometer No.	Sump El 228	Sump El 229	Sump El 230	Sump El 231	Sump El 235.5
56	+0.1	+0.1	+0.1	+0.1	0.0
57	-0.3	-0.5	-0.6	-0.2	-0.6
58	-0.1	-0.2	-0.2	-0.15	-0.2
59	-0.2	-0.2	-0.2	0.0	-0.2
60	-0.2	-0.1	-0.1	-0.2	-0.2
61	-0.1	-0.1	-0.1	-0.1	-0.1
62	-0.1	-0.1	-0.1	-0.1	-0.1
63	-0.1	-0.1	-0.1	-0.1	-0.1
64	-0.1	-0.1	-0.1	-0.1	-0.2
65	-0.1	-0.1	-0.1	-0.1	-0.2
66	-0.1	-0.1	-0.1	-0.1	-0.2
67	-0.1	-0.1	-0.1	-0.1	-0.2
68	-0.1	-0.1	-0.1	-0.1	-0.2
69	-0.1	-0.1	-0.1	-0.1	-0.1
70	-0.1	-0.1	-0.1	-0.1	-0.1
71	-0.2	-0.1	-0.1	-0.1	0.0
72	+0.1	-0.1	+0.1	+0.1	0.0
73	+0.1	-0.1	0.0	0.0	0.0
74	+0.1	+0.1	+0.1	-0.1	0.0
75	+0.1	+0.1	+0.1	-0.1	0.0
76	+0.1	+0.1	+0.1	-0.1	0.0
77	+0.1	+0.2	+0.2	-0.1	0.0
78	-0.6	-0.5	-0.2	-0.2	-0.4
79	-0.2	-0.2	-0.1	-0.1	-0.3
80	-0.1	-0.2	-0.1	-0.1	-0.2
81	-0.1	-0.2	-0.1	-0.1	-0.2
82	-0.1	-0.2	-0.1	-0.1	-0.2
83	-0.1	-0.2	-0.1	-0.1	-0.1
84	-0.1	-0.2	-0.1	-0.1	-0.1



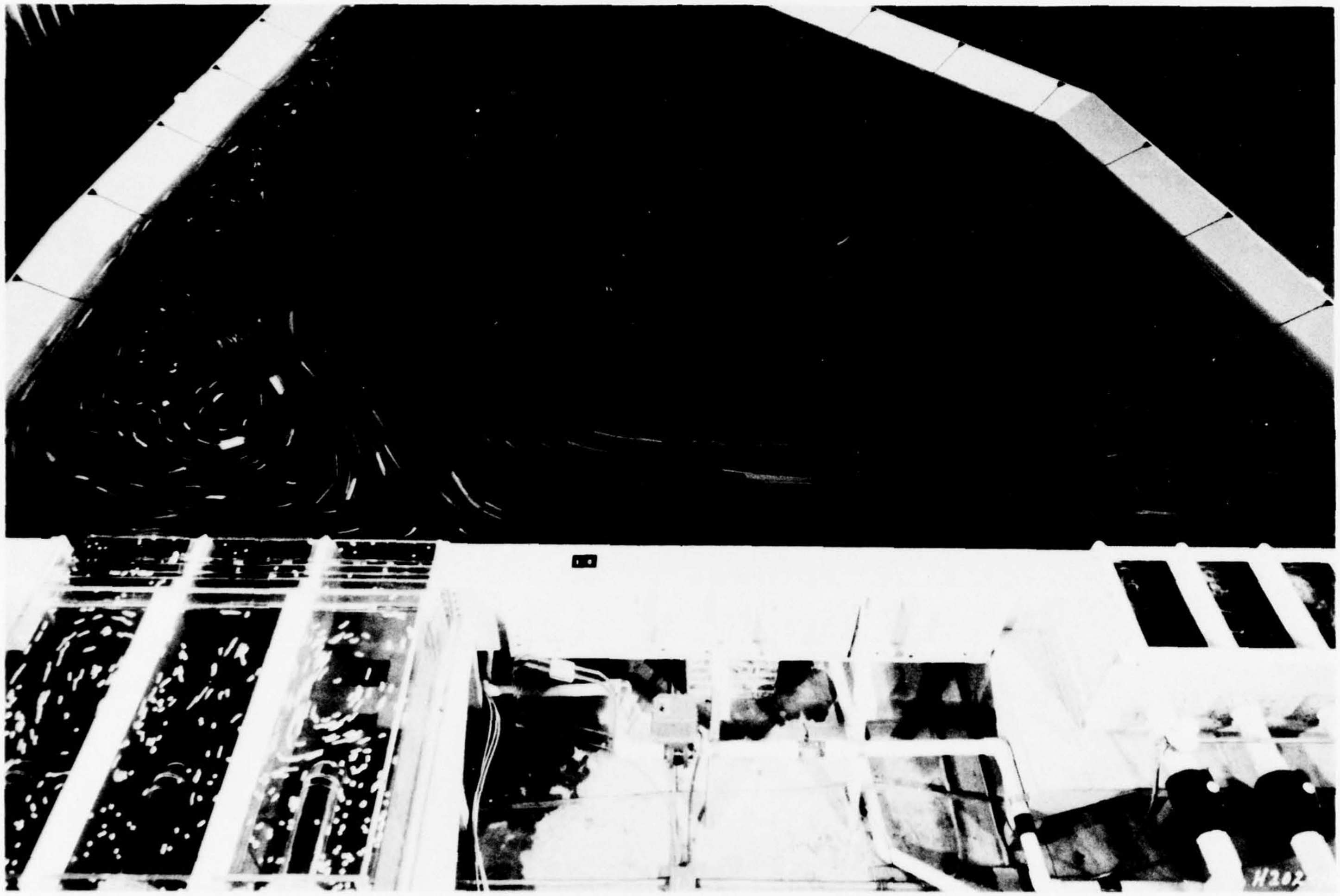
a. Proposed station operating independently

Photo 1. Flow patterns in approach channel (original design); sump el 228 (sheet 1 of 2)



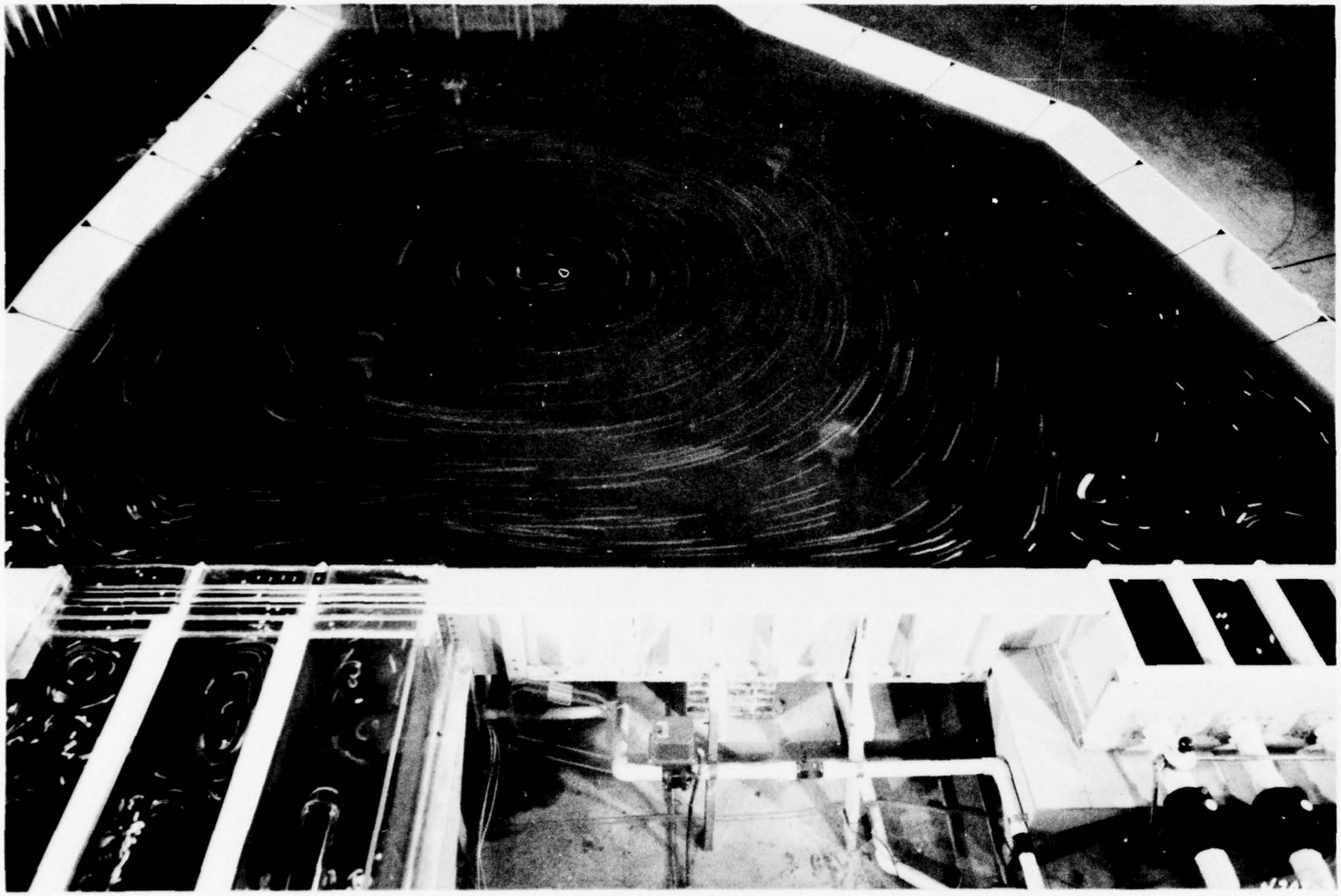
b. Both stations operating

Photo 1 (sheet 2 of 2)



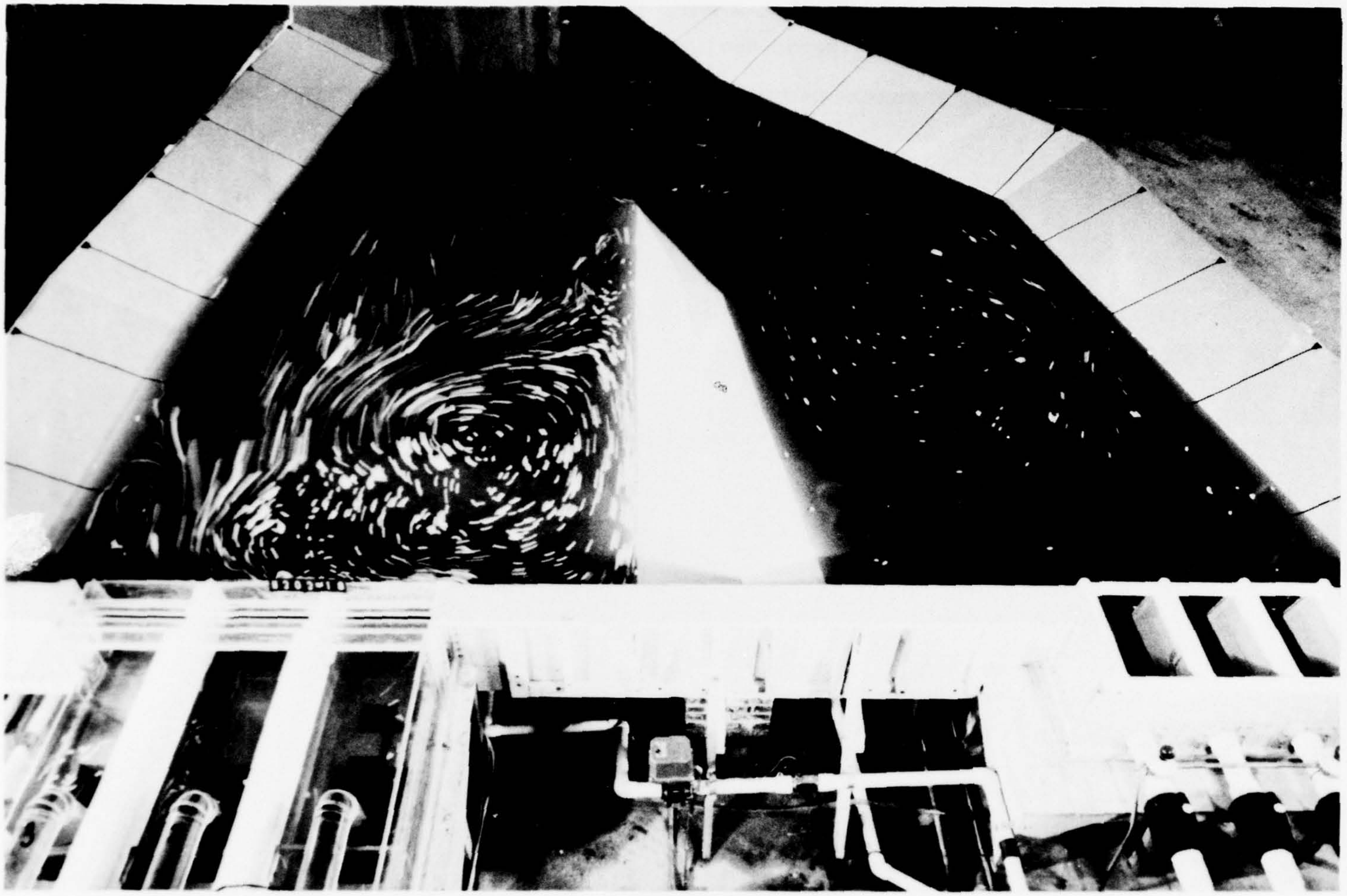
a. Proposed station operating independently

Photo 2. Flow patterns in approach channel (original design); sump el 235.5 (sheet 1 of 2)



b. Both stations operating

Photo 2 (sheet 2 of 2)

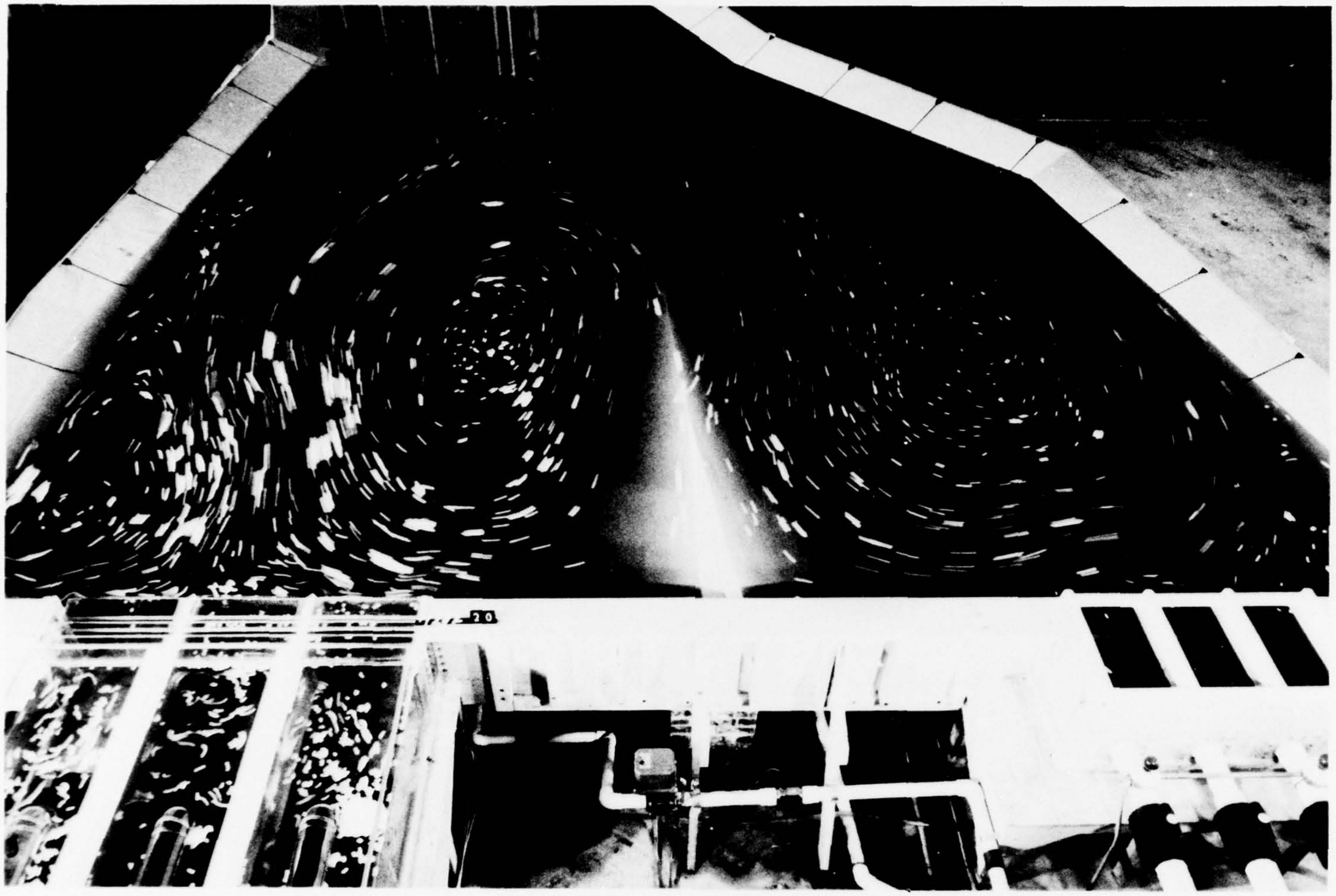


a. Proposed station operating independently

Photo 3. Flow patterns in approach channel (type 2); sump el 228 (sheet 1 of 2)

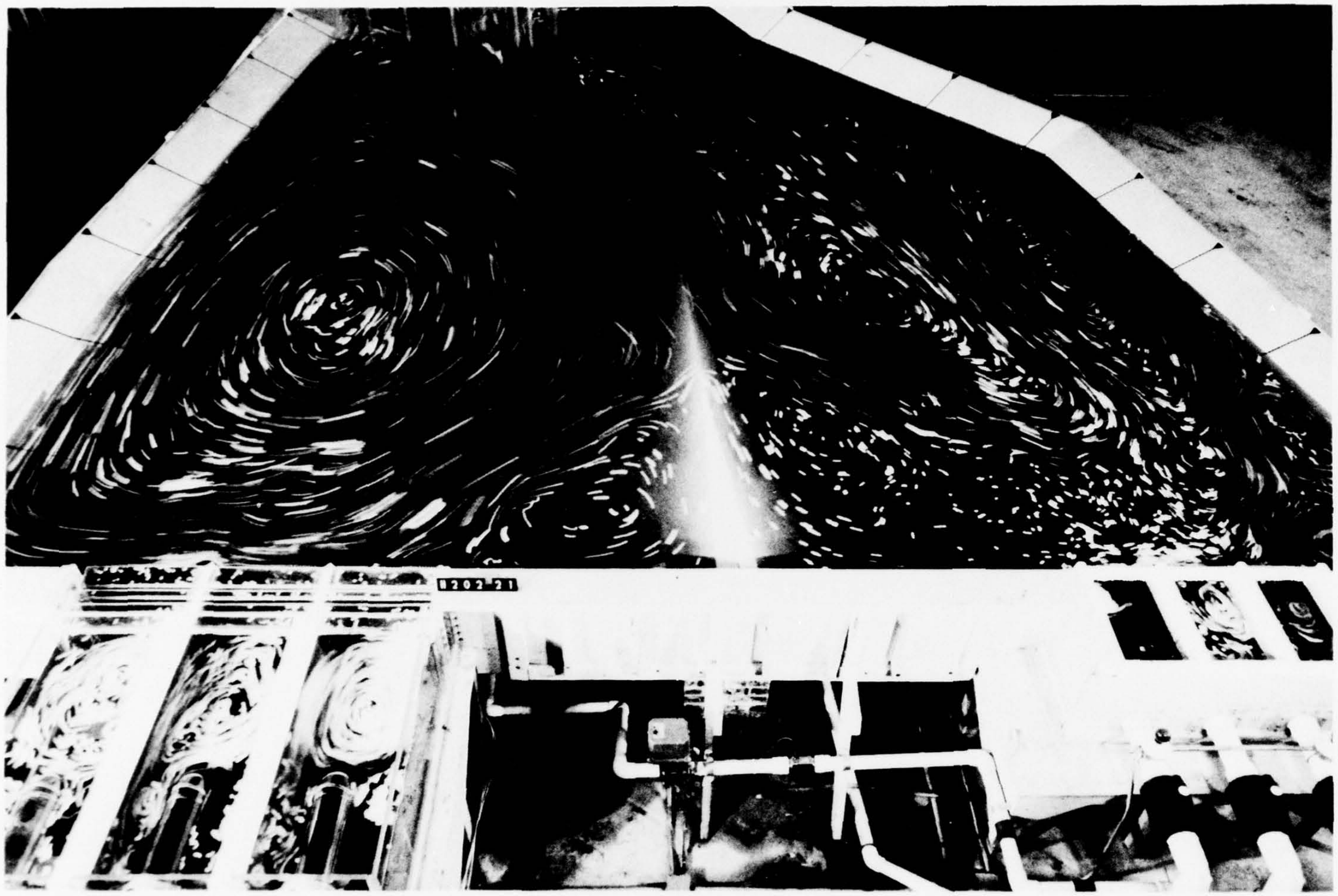
b. Both stations operating

Photo 3 (sheet 2 of 2)



a. Proposed station operating independently

Photo 4. Flow patterns in approach channel (type 2); sump el 235.5 (sheet 1 of 2)



b. Both stations operating

Photo 4 (sheet 2 of 2)

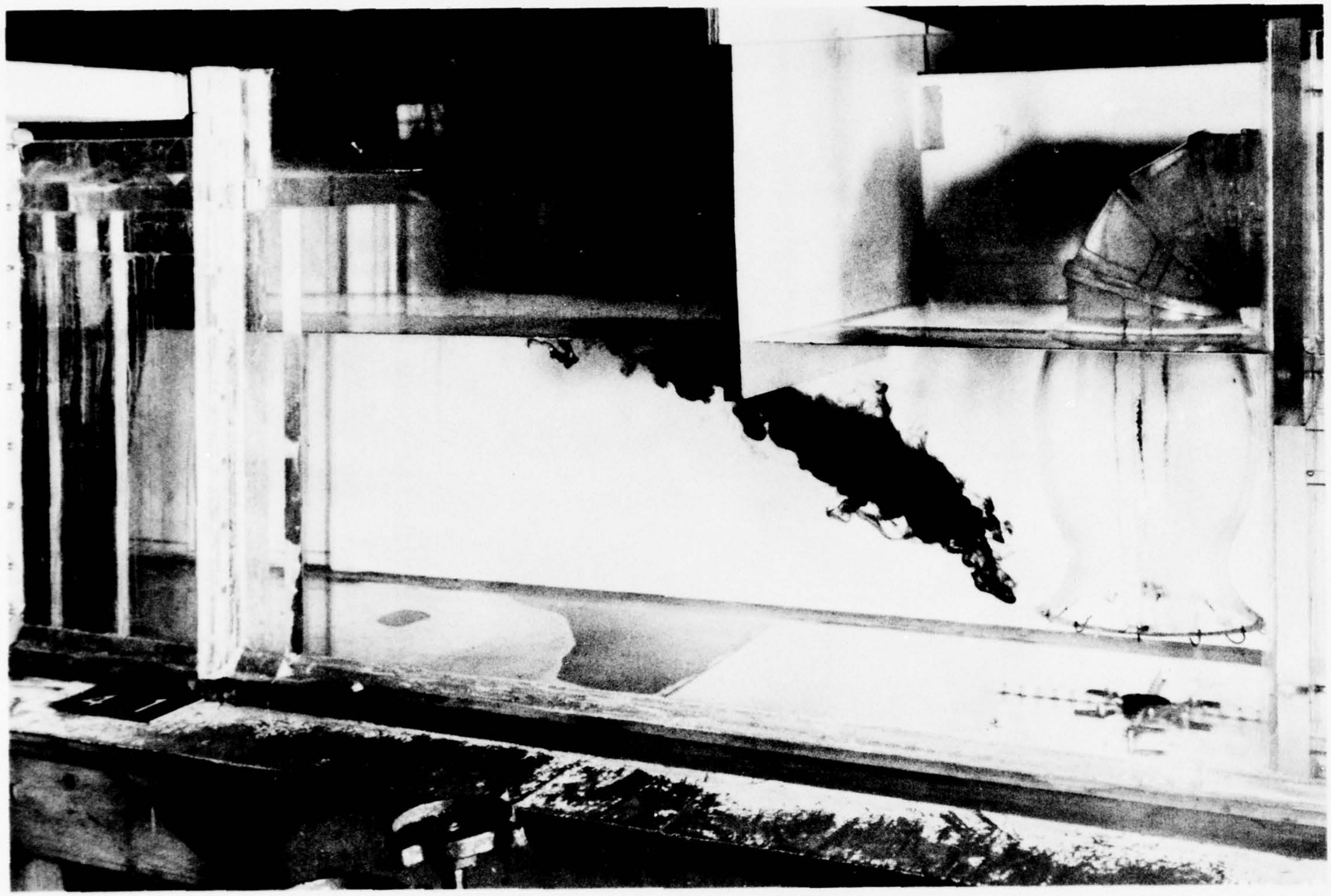


Photo 5. Recommended baffle wall for blocking surface flow above el 230; sump el 231

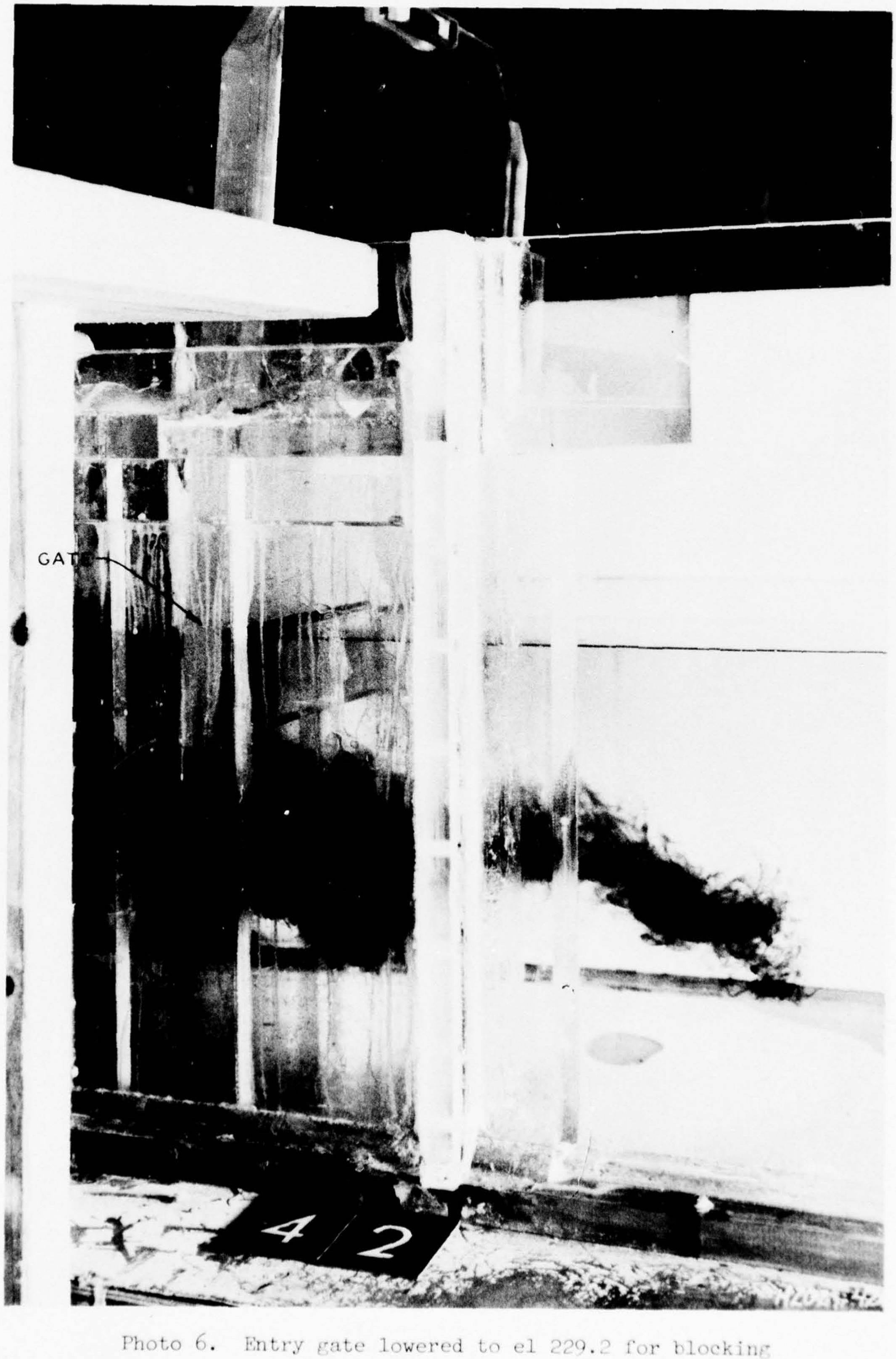
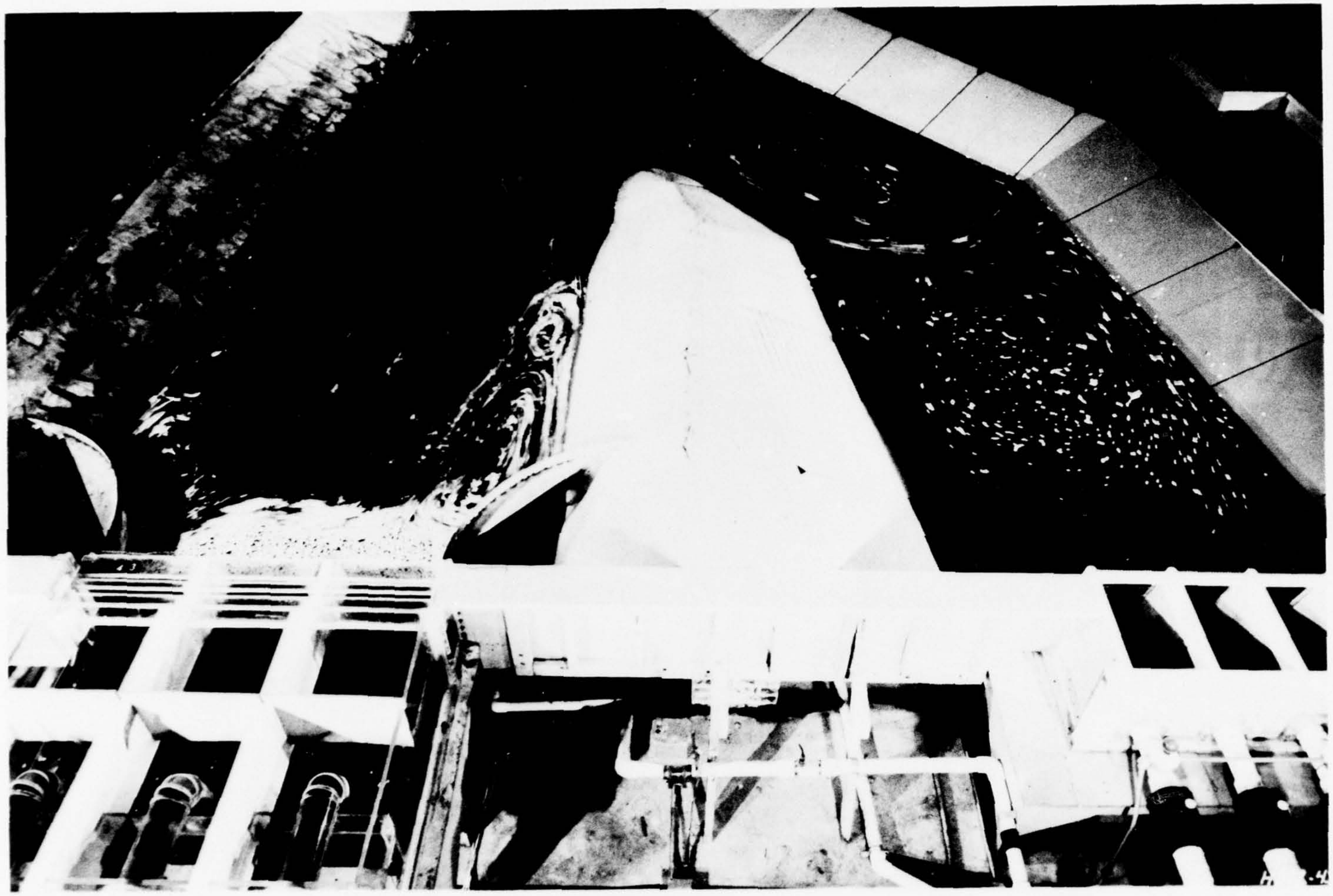
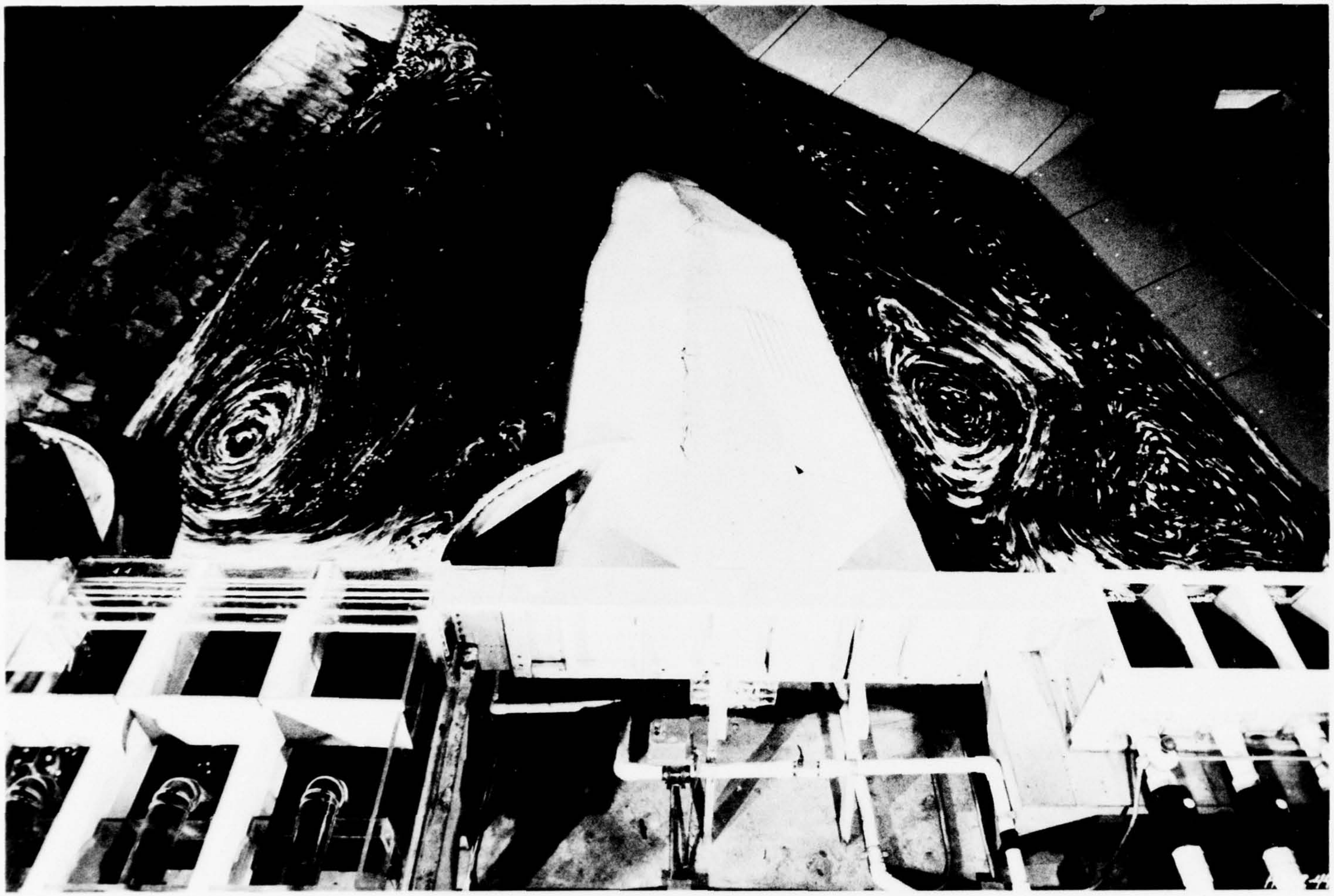


Photo 6. Entry gate lowered to el 229.2 for blocking
surface flow; sump el 231



a. Proposed station operating independently

Photo 7. Flow patterns with recommended design; sump el 228 (sheet 1 of 2)

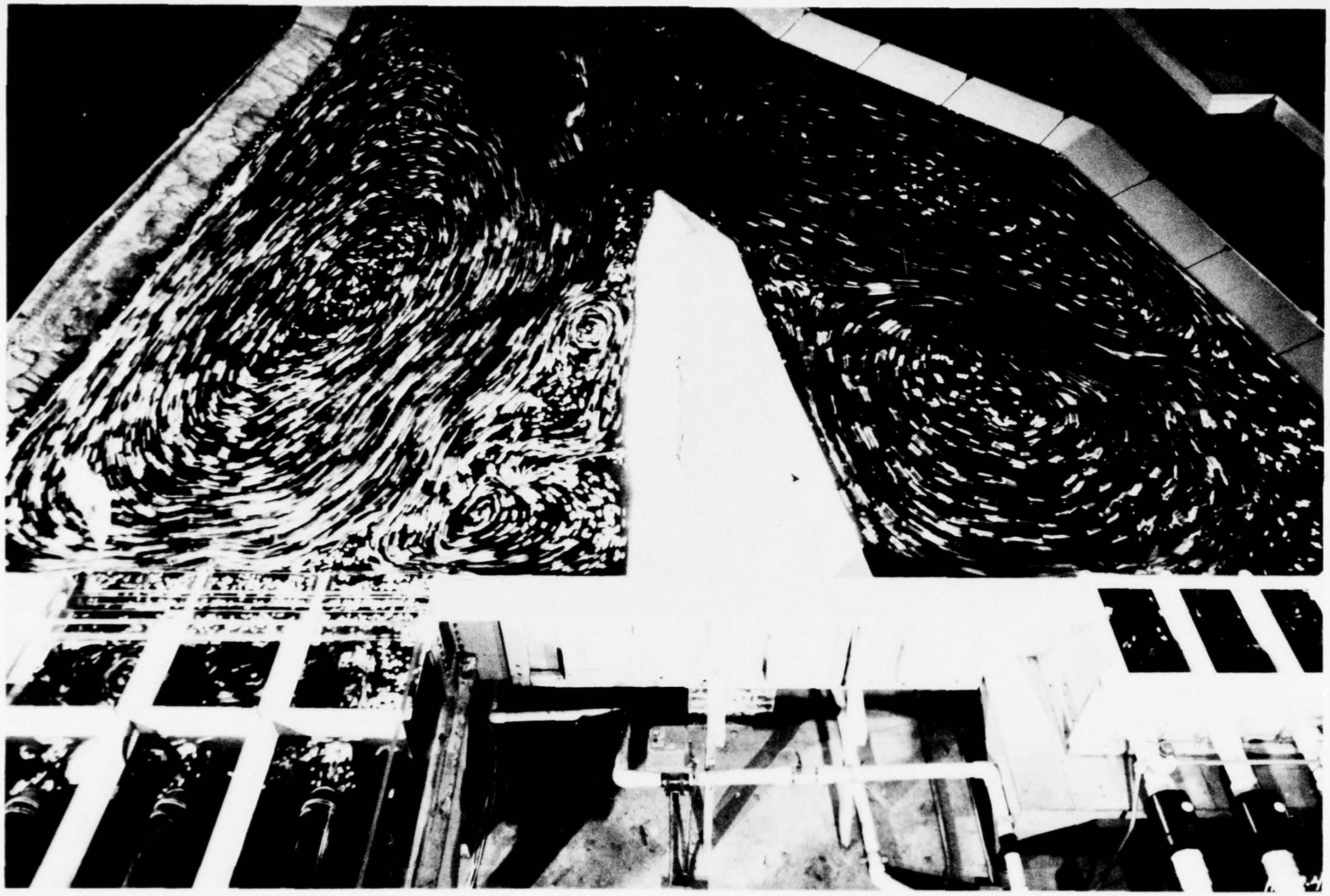


b. Both stations operating

Photo 7 (sheet 2 of 2)

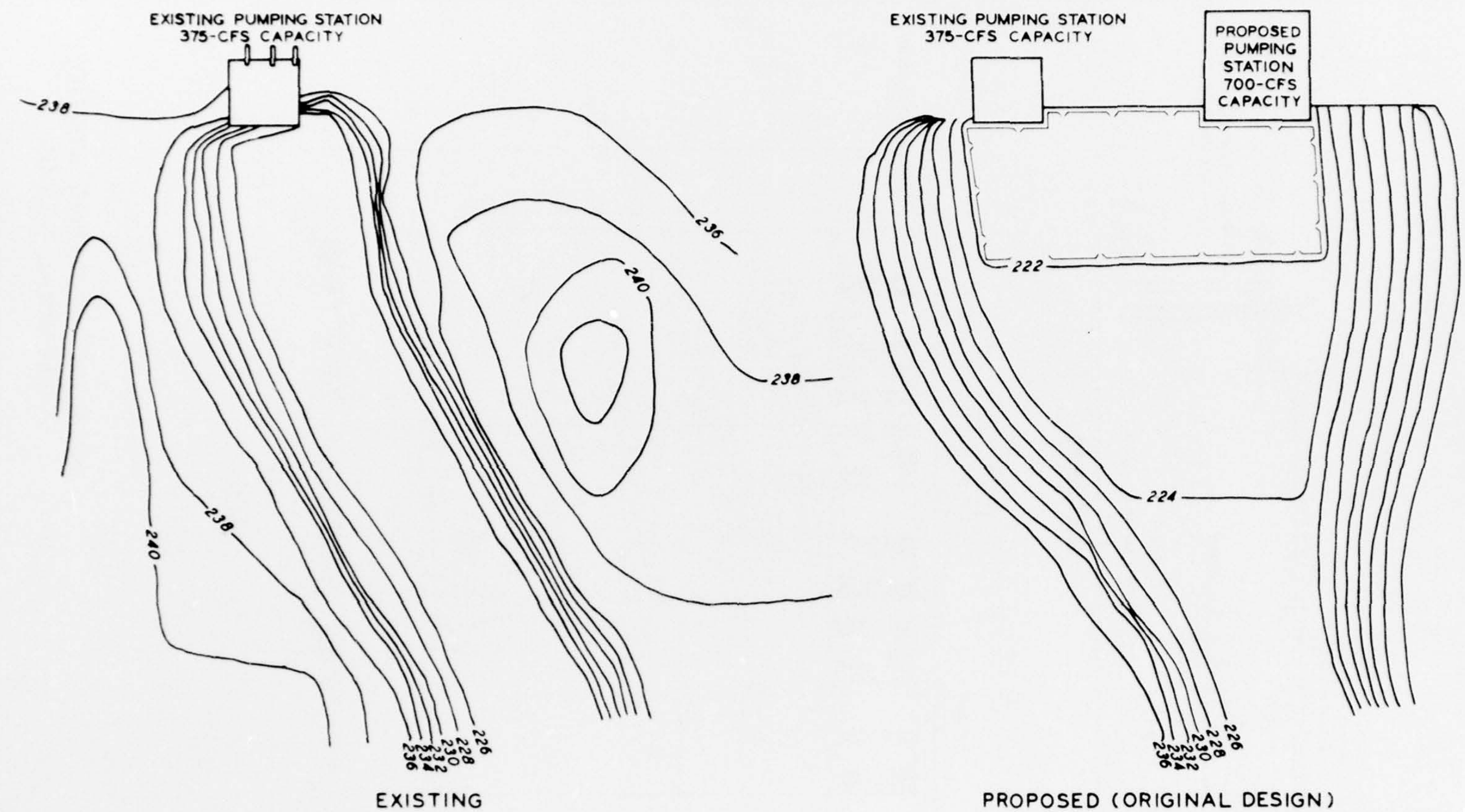
a. Proposed station operating independently

Photo 8. Flow patterns with recommended design; sump el 235.5 (sheet 1 of 2)

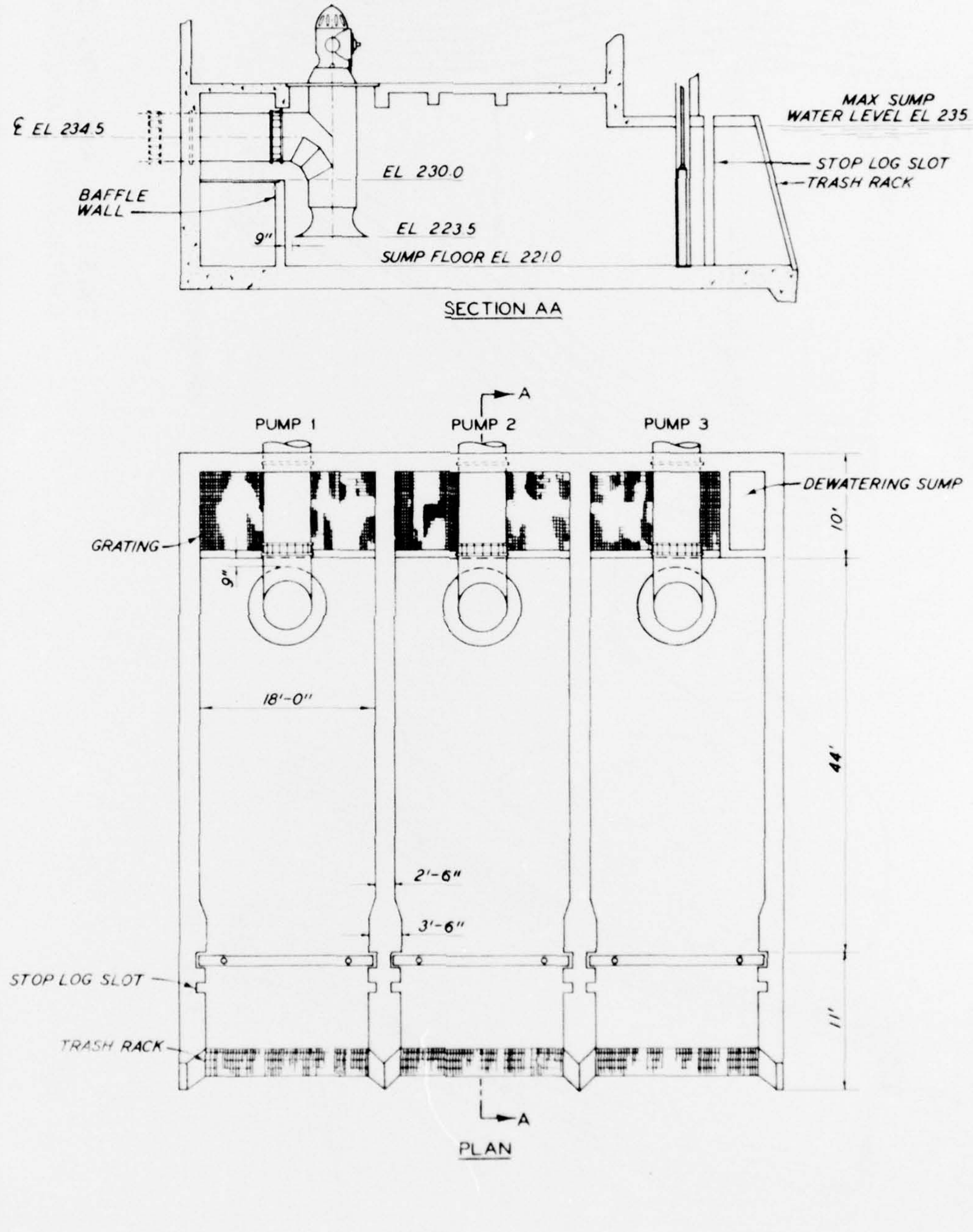


b. Both stations operating

Photo 8 (sheet 2 of 2)

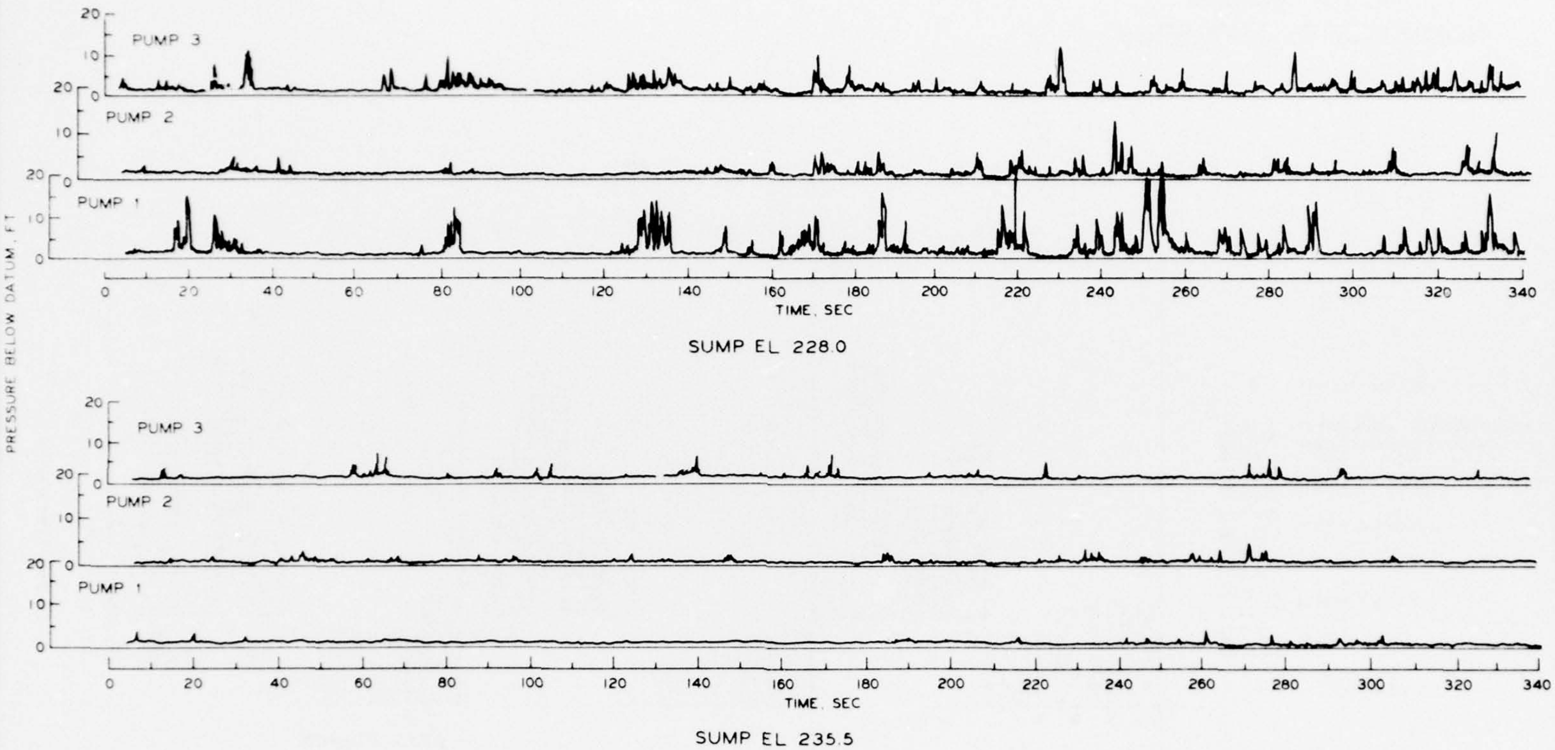


EXISTING AND PROPOSED
APPROACH TOPOGRAPHY



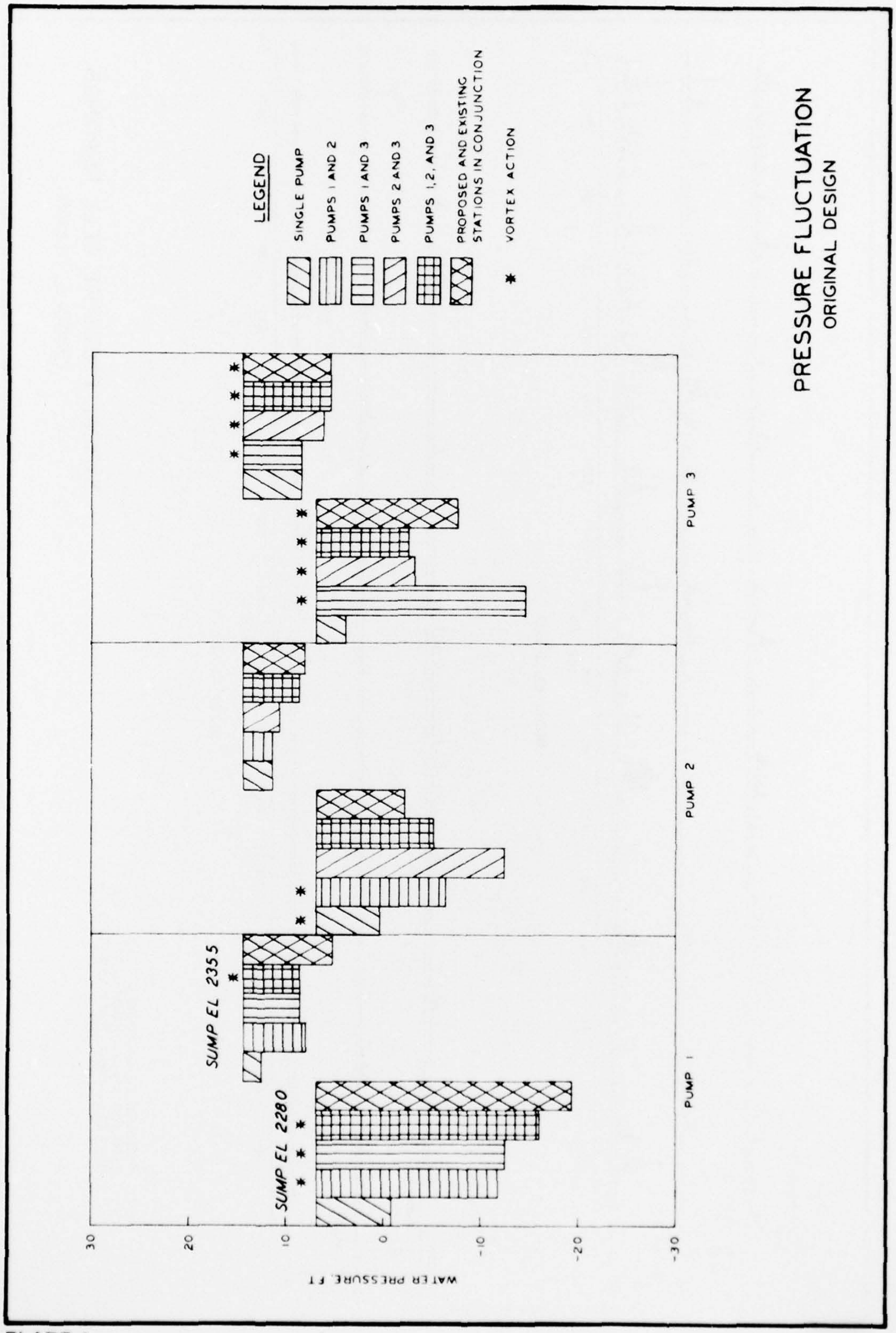
PROPOSED PUMPING STATION
(ORIGINAL DESIGN)

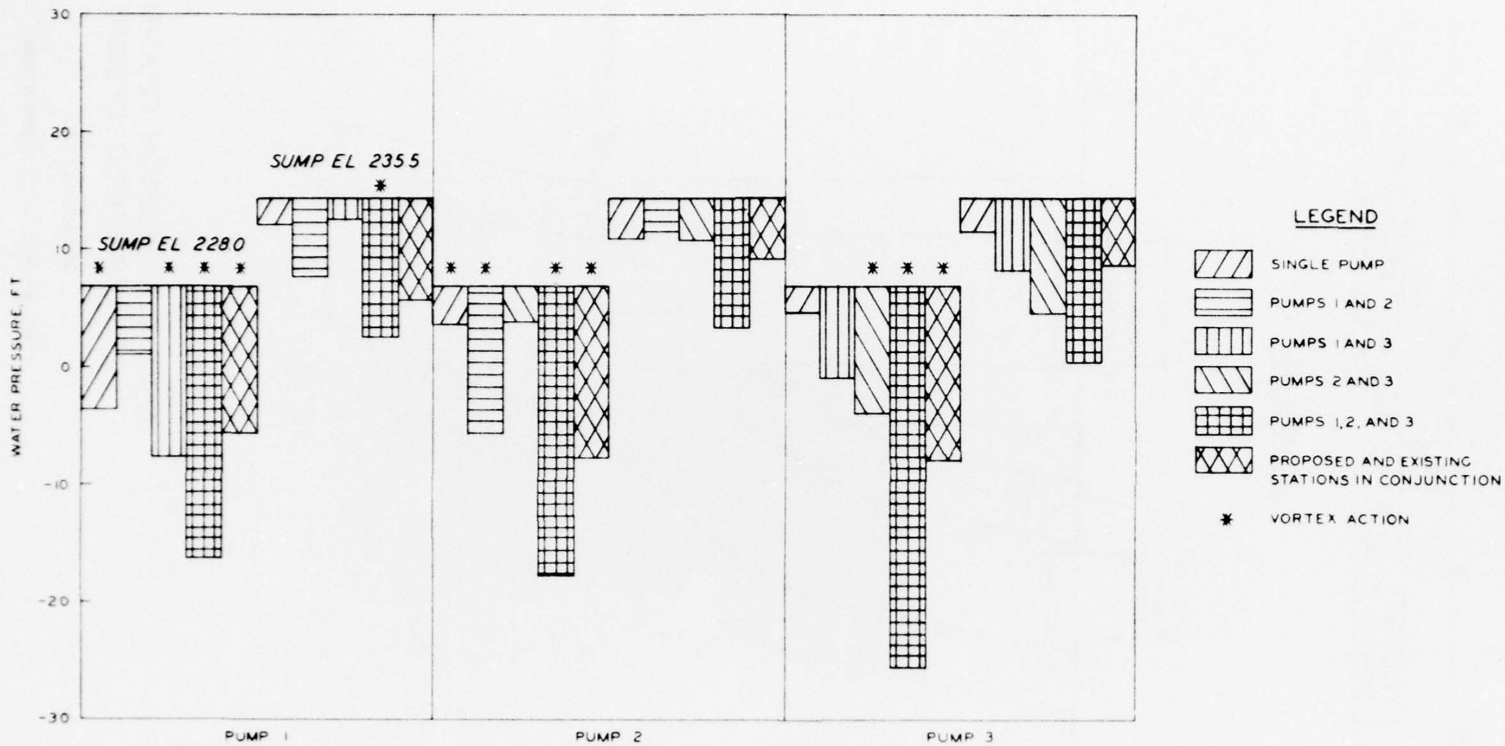
PLATE 2



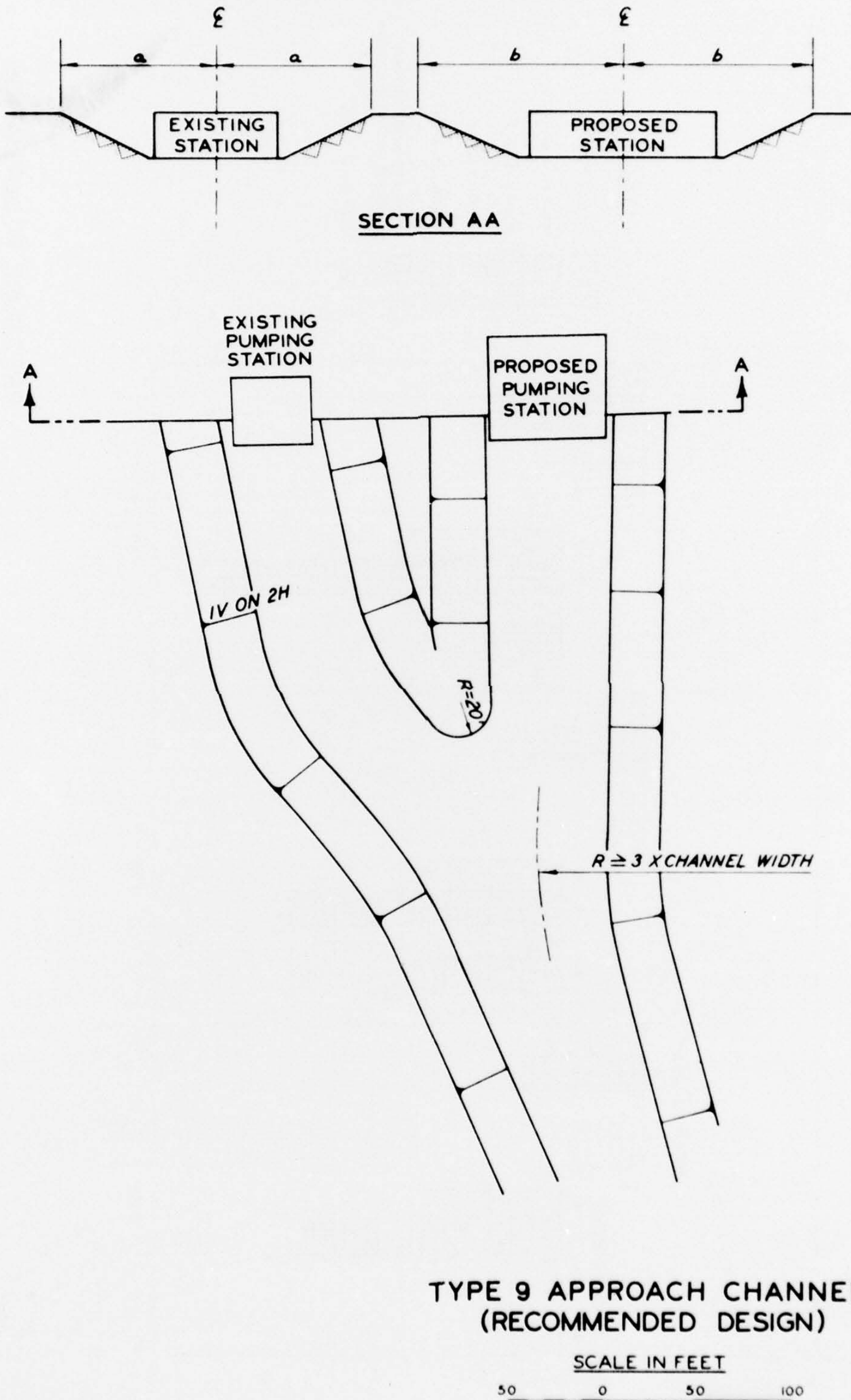
NOTE: PRESSURE CELLS WERE SET AT ZERO FOR STATIC LOADING WITH SUMP ELEVATIONS 228.0 AND 235.5

TYPICAL PRESSURE CELL READINGS
ORIGINAL DESIGN

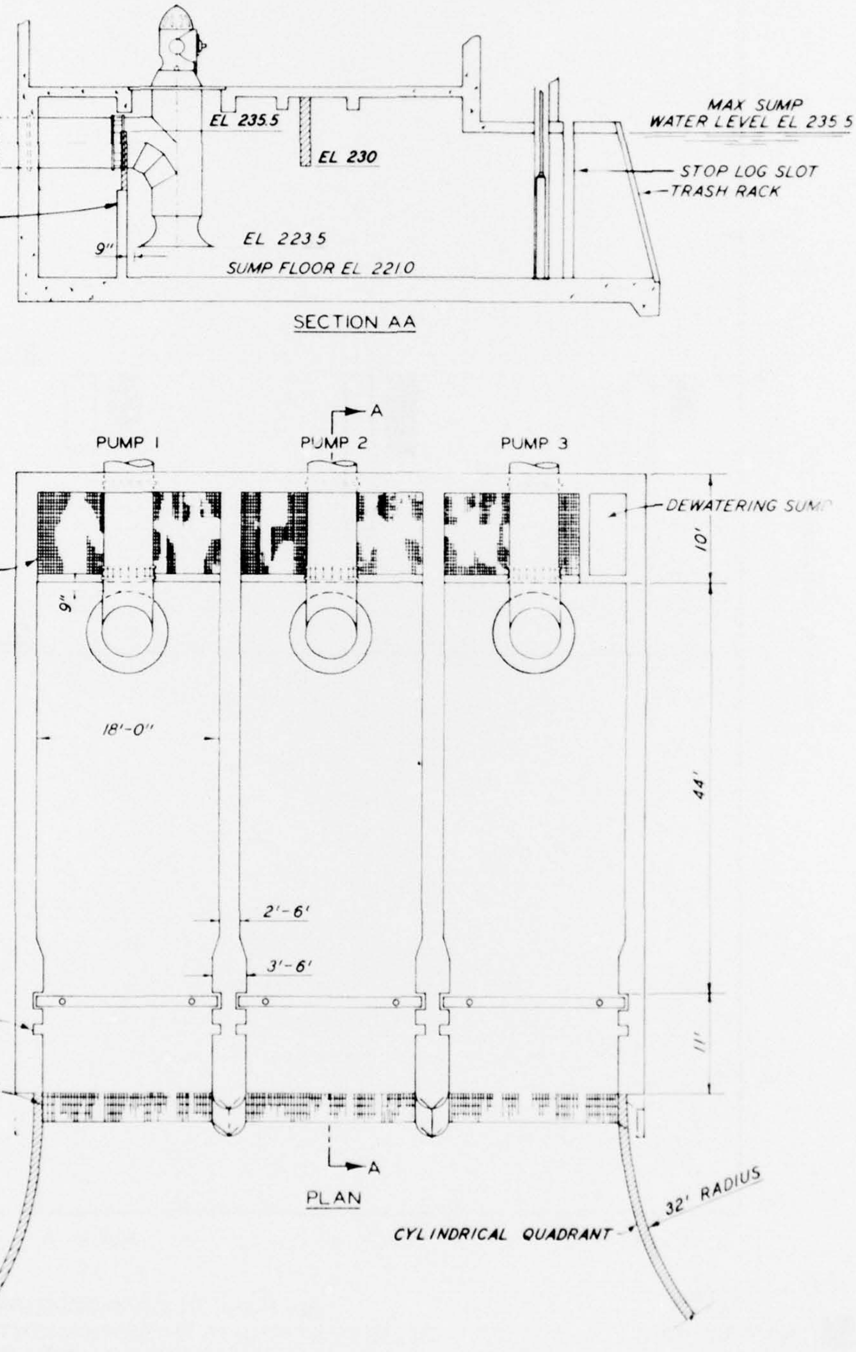

PRESSURE FLUCTUATION
ORIGINAL DESIGN
LEGEND
SINGLE PUMP
PUMPS 1 AND 2
PUMPS 1 AND 3
PUMPS 2 AND 3
PUMPS 1, 2, AND 3
PROPOSED AND EXISTING STATIONS IN CONJUNCTION
VORTEX ACTION
WATER PRESSURE, FT
30
20
10
0
-10
-20
-30
PUMP 1
PUMP 2
PUMP 3
SUMP EL 228.0
SUMP EL 235.5



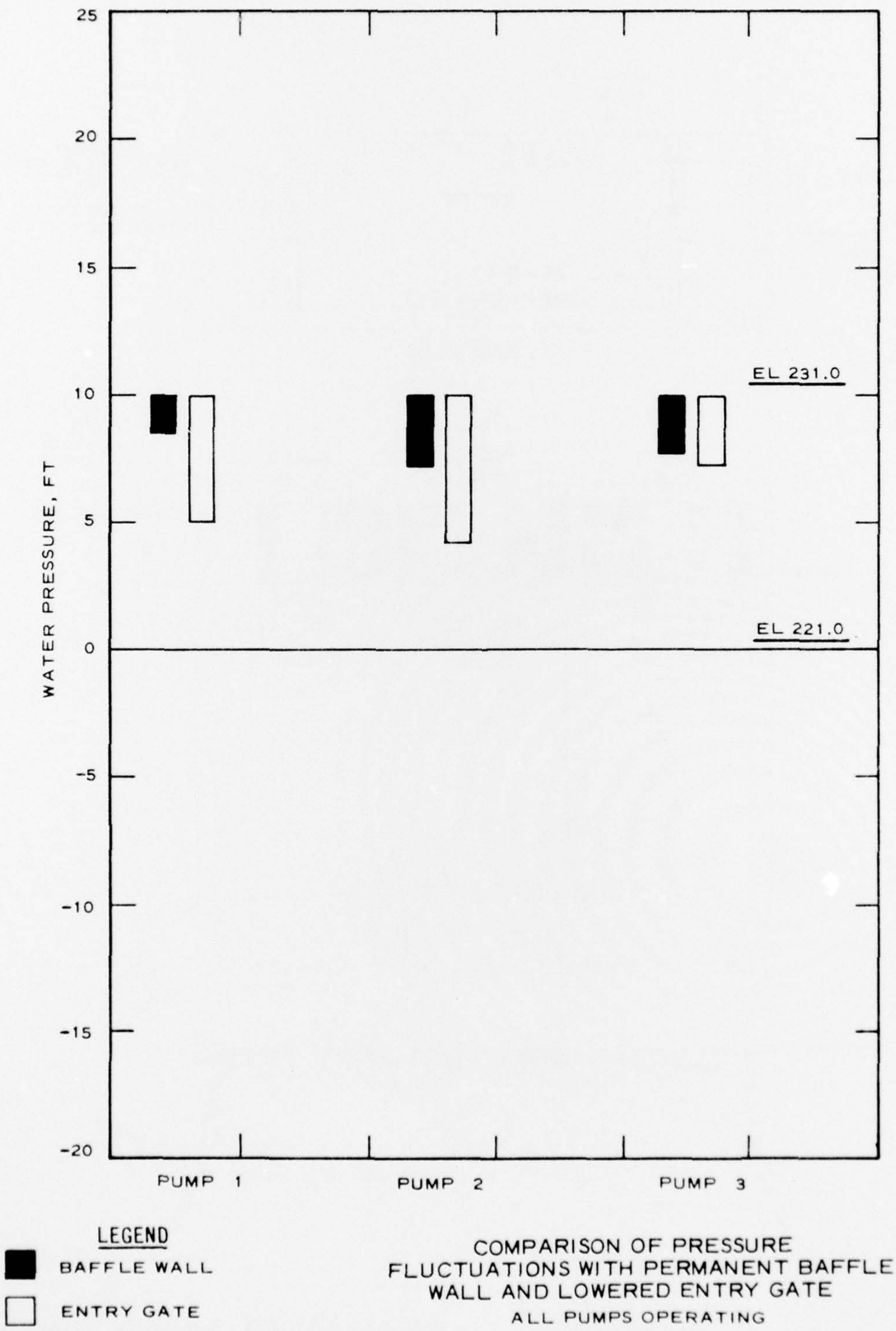
PRESSURE FLUCTUATION
TYPE 2 APPROACH CHANNEL



TYPE 9 APPROACH CHANNEL
(RECOMMENDED DESIGN)



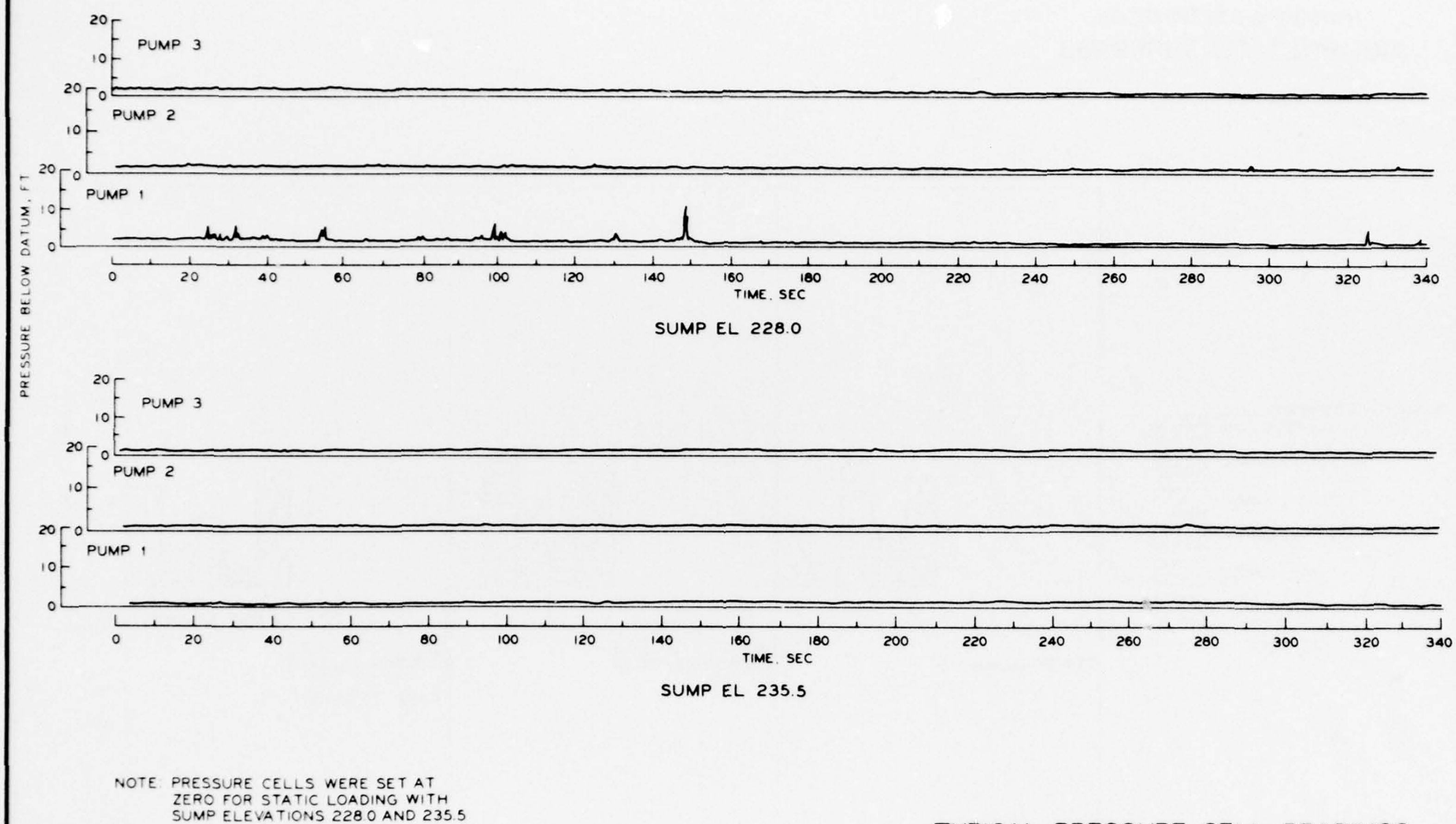
RECOMMENDED SUMP DESIGN



COMPARISON OF PRESSURE FLUCTUATIONS WITH PERMANENT BAFFLE WALL AND LOWERED ENTRY GATE

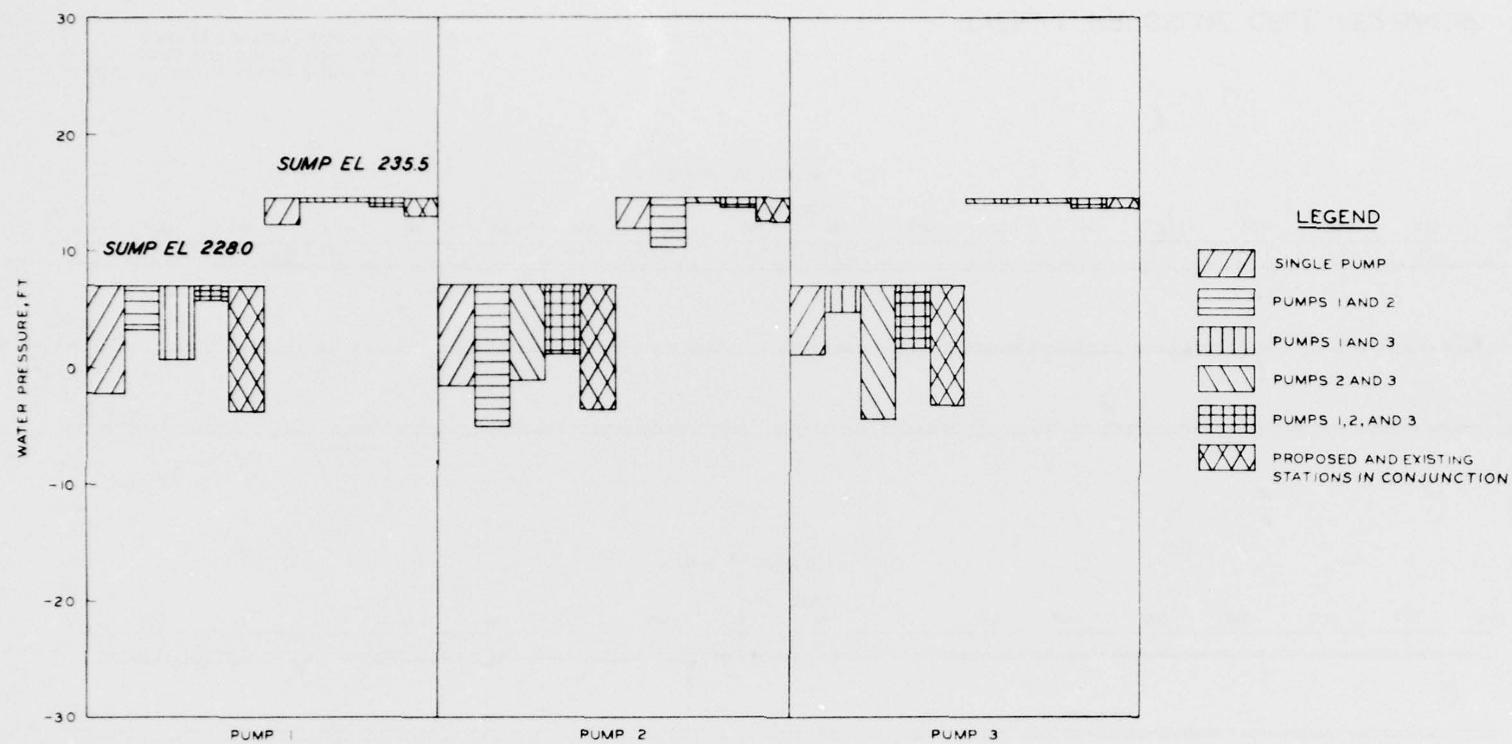
ALL PUMPS OPERATING

SUMP EL 231



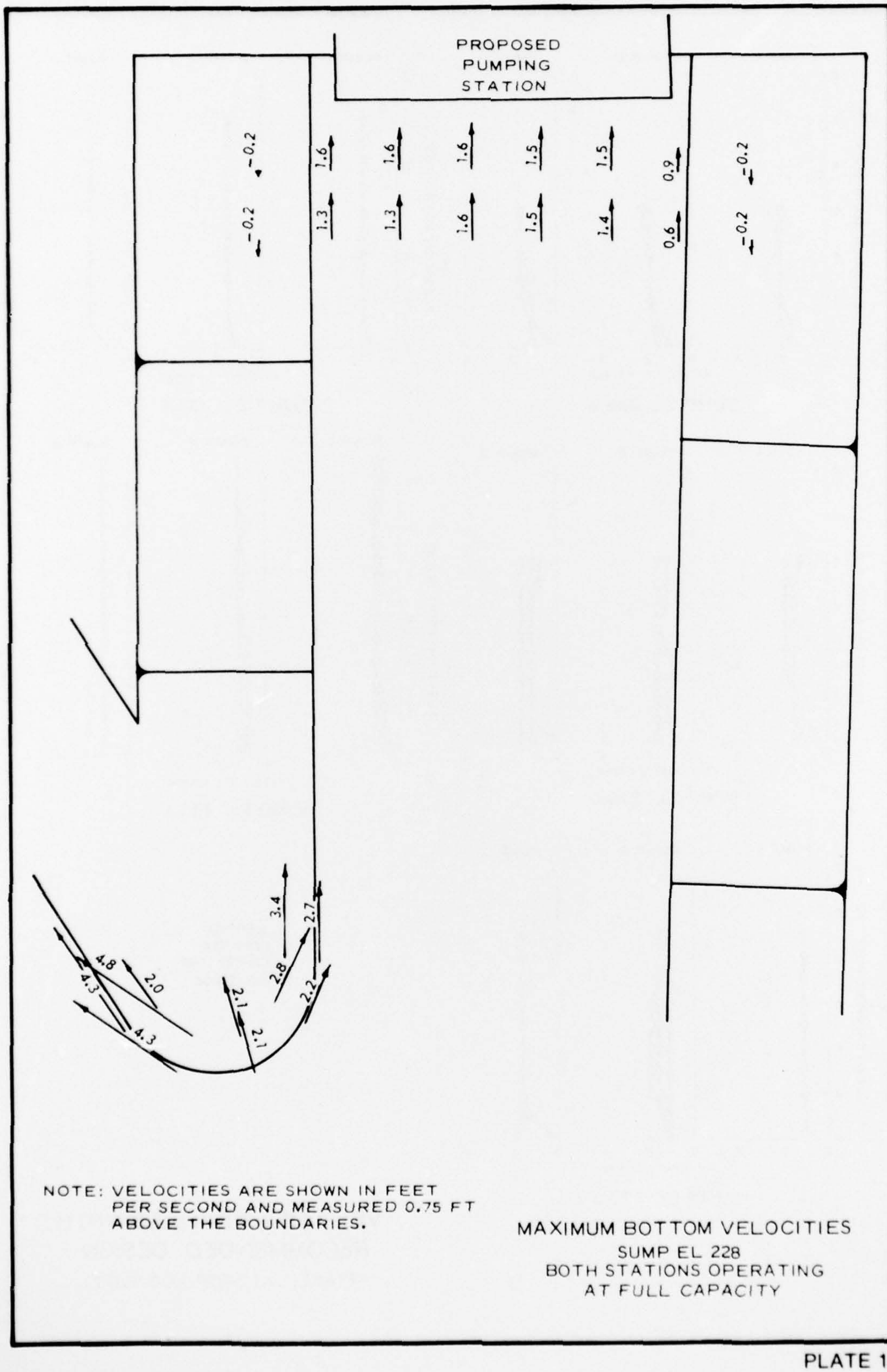
TYPICAL PRESSURE CELL READINGS

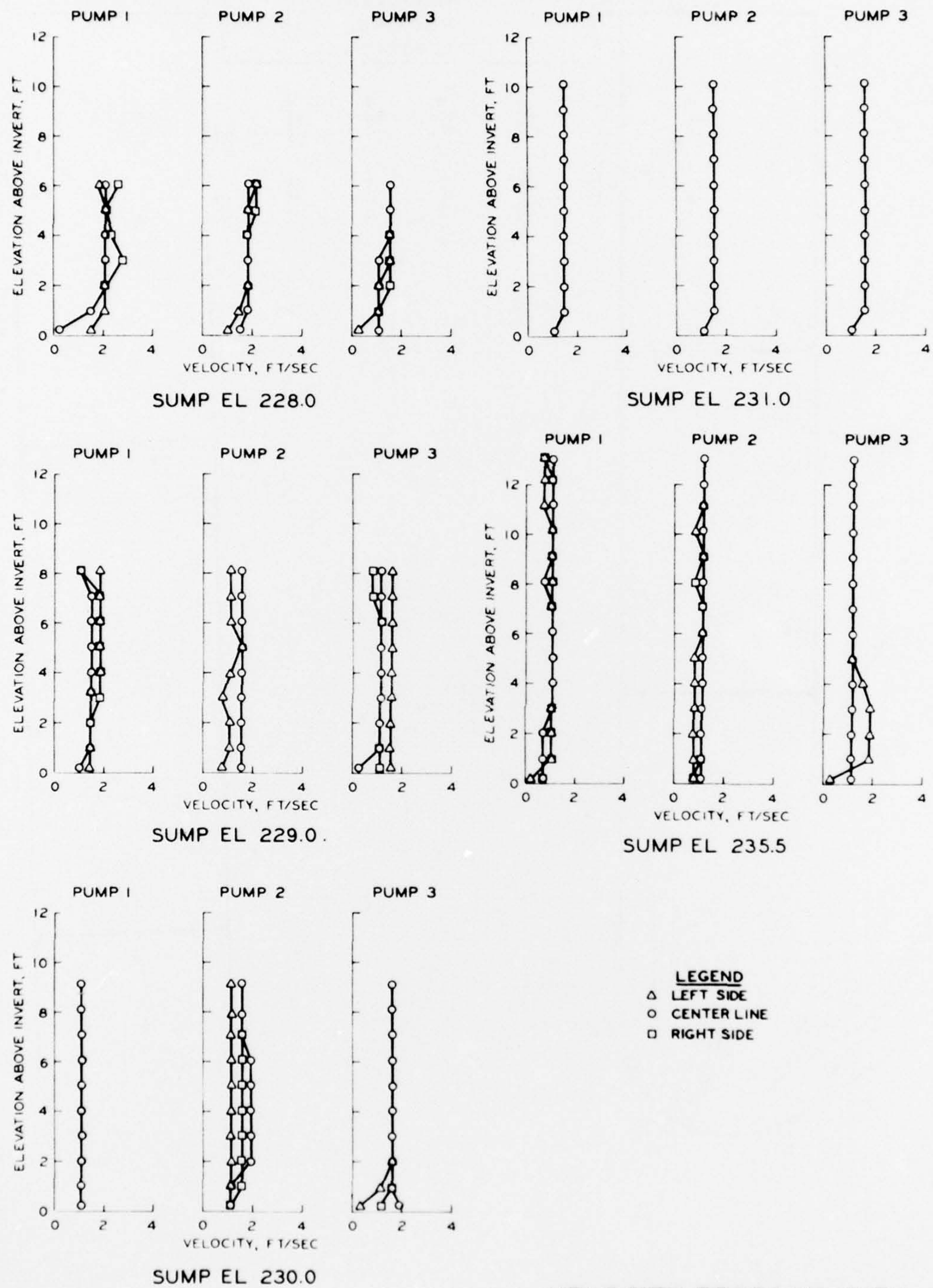
RECOMMENDED DESIGN



PRESSURE FLUCTUATION
RECOMMENDED DESIGN

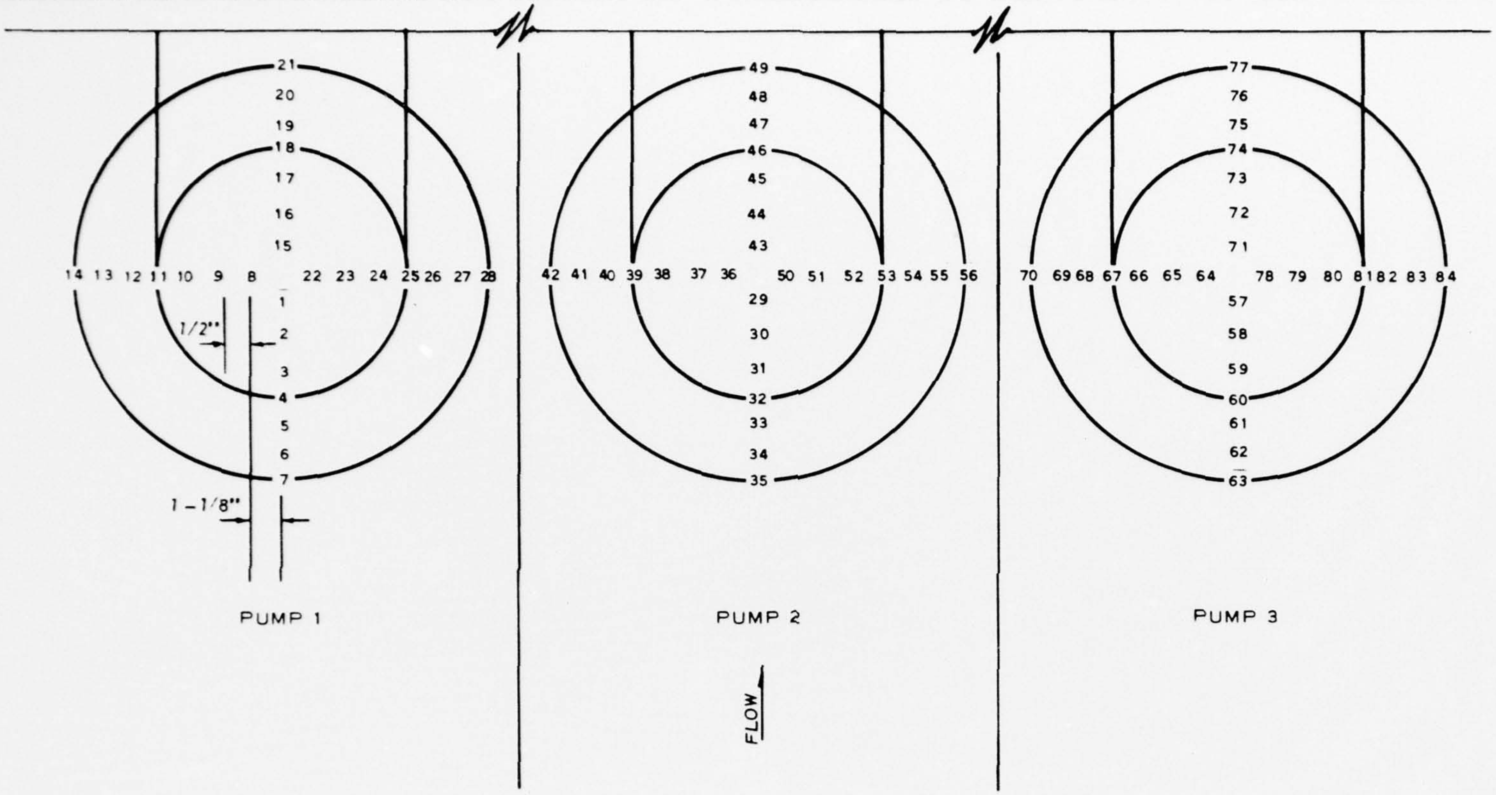
PLATE 10


PROPOSED
PUMPING
STATION
1.6
1.6
1.6
1.5
1.5
0.9
-0.2
-0.2
1.3
1.3
1.6
1.5
1.4
0.6
-0.2
-0.2
3.4
2.7
2.8
2.2
4.8
2.0
4.3
2.1
2.1
4.3
NOTE: VELOCITIES ARE SHOWN IN FEET
PER SECOND AND MEASURED 0.75 FT
ABOVE THE BOUNDARIES.
MAXIMUM BOTTOM VELOCITIES
SUMP EL 228
BOTH STATIONS OPERATING
AT FULL CAPACITY



VELOCITY PROFILES WITH RECOMMENDED DESIGN
(TAKEN AT STOP LOG SLOT)

PLATE 12



PIEZOMETER LOCATIONS
1/4-IN. PIEZOMETER TAPS ON 1/2-IN. CENTERS

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Saunders, Peter E
Pumping stations for Drainage District No. 17, Mississippi County, Arkansas; hydraulic model investigation, by Peter E. Saunders. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report H-77-12)
Prepared for U. S. Army Engineer District, Memphis, Memphis, Tenn.
Includes bibliography.

1. Drainage District No. 17. 2. Hydraulic models. 3. Open channel flow. 4. Pumping stations. 5. Vortexes. I. U. S. Army Engineer District, Memphis. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report H-77-12)
TA7.W34 no.H-77-12